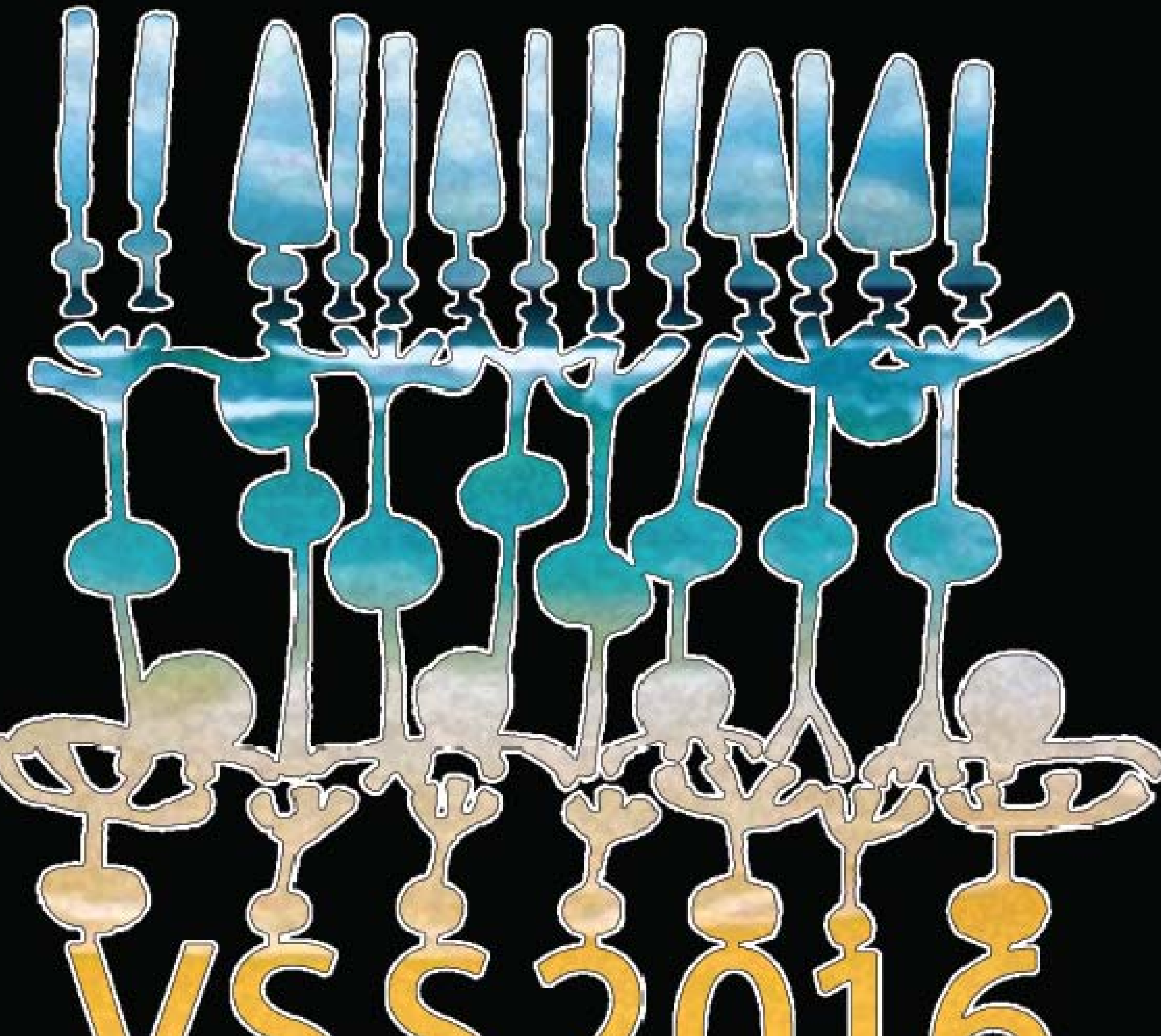
VISION SCIENCES SOCIETY



ABSTRACTS

16th Annual Meeting, May 13-18, 2016
St. Pete Beach, Florida

Vision Sciences Society

16th Annual Meeting, May 13-18, 2016

TradeWinds Island Resorts, St. Pete Beach, Florida

Abstracts

Contents

Program and Abstracts cover designs by **Michael Barnett**, Stanford University
T-shirt, mug, and tote design by **Rain Jirui Li**, York University

Sessions Overview

Abstract Numbering System

Each abstract is assigned a unique 4 or 6 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	Third Digit - Room	Fourth-Sixth Digits - Number
2 Saturday	1 Early AM talk session	1 Talk Room 1	1, 2, 3... For talks
3 Sunday	2 Late AM talk session	2 Talk Room 2	001, 002... For posters
4 Monday	3 AM poster session	3 Banyan Breezeway	
5 Tuesday	4 Early PM talk session	4 Pavilion	
6 Wednesday	5 Late PM talk session		
	6 PM poster session		

Examples:
21.16 Saturday, early AM talk in Talk Room 1, 6th talk
36.3013 Sunday, PM poster in Banyan Breezeway, poster board 13
53.4106 Tuesday, AM poster in the Pavilion, poster board 106

Note: Two digits after the period indicates a talk, four digits indicates a poster (the last three digits are the board number).

Member-Initiated Symposia

Schedule Overview

Friday, May 13, 12:00 - 2:00 pm

S1 - Artifice versus realism as an experimental methodology Talk Room 1-2

S2 - Boundaries in Spatial Navigation and Visual Scene Perception Pavilion

Friday, May 13, 2:30 - 4:30 pm

S3 - What do deep neural networks tell us about biological vision? Talk Room 1-2

S4 - What can we learn from #TheDress – in search for an explanation Pavilion

Friday, May 13, 5:00 - 7:00 pm

S5 - ARVO@VSS: Information processing in a simple network: What the humble retina tells the brain. Talk Room 1-2

S6 - The parietal cortex in vision, cognition, and action Pavilion

S1 - Artifice versus realism as an experimental methodology

Friday, May 13, 12:00 - 2:00 pm, Talk Room 1-2

Organizer: Peter Scarfe, Department of Psychology, University of Reading, UK

Presenters: Tony Movshon, David Brainard, Roland Fleming, Johannes Burge, Jenny Read, Wendy Adams

The symposium will focus on the fine balance that all experimenters have to strike between adopting artifice or realism as an experimental methodology. As scientists, should we use stimuli and tasks that are extremely well characterized, but often bare little resemblance to anything someone would experience outside of an experiment? Or should we use realistic stimuli and tasks, but by doing so sacrifice some level of experimental control? How do we make valid inferences about brain and behavior based upon each approach, and is there a deal be struck, where we gain the best of both worlds? The symposium will bring together leading researchers who have taken differing approaches to satisfying the needs of realism and artifice. These will include those who have used artificial, or indeed physically impossible, stimuli to probe both 2D and 3D perception; those who have pioneered the use of photo-realistically rendered stimuli in experiments, and developed the tools for other experimenters to do so; and others who combine measurement of natural images statistics from the real world, with well characterized artificial stimuli during experiments. The research presented will cover perception and action in humans, non-human primates, and insects. Techniques will span both behavioral experiments as well as neurophysiology. All speakers will discuss the pros and cons of their approach and how they feel the best balance can be struck between ecological validity and experimental control. The symposium will be relevant to anyone attending VSS, whether student, postdoc, or faculty. In terms of benefits gained, we want to both inspire those at the start of their career, as well as provoke those with established research programs to consider alternative approaches. The aim is to give the audience an insight into how best to design experiments to make valid inferences about brain and behavior. The scientific merit of this is clear; at whatever stage of our research career, we as scientists should constantly be questioning our beliefs about the validity of our research with respect to the real world. The topic of the symposium is highly original and has never been more timely. With existing technology, it is possible to simulate parametrically-controlled photo-realistic stimuli that cannot be distinguished from real photographs. We can also map the statistics of the world around us in exquisite detail. Combine this with the prospect of affordable virtual reality in the near future, running highly-realistic experiments has never been easier. Despite this, the vast majority of experiments still use very artificial stimuli and tasks. It is only by defining and debating what we mean by "realism" and "artifice" that we will understand if this is a problem, and whether a fundamental shift is needed for us to truly understand the brain.

Using artifice to understand nature

Speaker: Tony Movshon, NYU

Vision evolved to function in the natural world, but that does not mean that we need to use images of that world to study vision. Synthetic stimuli designed to test hypotheses about visual encoding and representation (e.g. lines, edges, gratings, random dot kinematograms and stereograms, textures with controlled statistics have given us a clear picture of many specific visual mechanisms, and allow principled tests of theories of visual function. What more could a reasonable person want?

The use of graphics simulations in the study of object color appearance

Speaker: David Brainard; University of Pennsylvania

Additional Authors: Ana Radonjić, Department of Psychology, University of Pennsylvania

A central goal in the study of color appearance is to develop and validate models that predict object color appearance from a physical scene description. Ultimately, we seek models that apply for any stimulus, and particularly for stimuli typical of natural viewing. One approach is to study color appearance using real illuminated objects in quasi-natural arrangements. This approach has the advantage that the measurements are likely to capture what happens for natural viewing. It has the disadvantage that it is challenging to manipulate the stimuli parametrically in theoretically interesting ways. At the other extreme, one can choose simplified stimulus sets (e.g., spots of light on uniform backgrounds, or 'Mondrian' configurations). This approach has the advantage that complete characterization of performance within the set may be possible, and one can hope that any principles developed will have general applicability. On the other hand, there is no a priori guarantee that what is learned will indeed be helpful for predicting what happens for real illuminated objects. Here we consider an intermediate choice, the use of physically-accurate graphics simulations. These offer the opportunity for precise stimulus specification and control; particularly interesting is the ability to manipulate explicitly distal (object and illuminant) rather than proximal (image) stimulus properties. They also allow for systematic introduction of complexities typical of natural stimuli, thus making it possible to ask what features of natural viewing affect performance and providing the potential to bridge between the study of simplified stimuli and the study of real illuminated objects.

Confessions of a reluctant photorealist

Speaker: Roland Fleming, Dept. of Experimental Psychology, University of Giessen

For some scientific questions, highly reduced stimuli are king. Sine waves. Gabors. Points of light. When paired with rigorous theory, such stimuli provide scalpel-like tools of unparalleled precision for dissecting sensory mechanisms. However, even the most disciplined mind is wont at times to turn to questions of subjective visual appearance. Questions like 'what makes silk look soft?', 'why does honey look runny?' or 'how can I tell wax is translucent?'. In order to study such complex phenomena (fluid flow, subsurface scattering, etc.), there simply is no alternative to using 'real' or 'photorealistic' stimuli, as these remain the only extant stimuli that elicit the relevant percepts. I will briefly describe a couple of my own experiments using computer simulations of complex physical processes to study the visual appearance of materials and the underlying visual computations. I will discuss both boons and perils of using computer simulations to study perception. On the one hand, the phenomena are horrendously complex and we still lack experimental methods for bridging the gap between discrimination and subjective appearance. On the other hand, simulations provide an unprecedented level of parametric control over complex processes, as well as access to the ground truth state of the scene (shape, motion, ray paths, etc). Finally, I will argue that using and analysing simulations is a necessary step in the development of more focussed, reduced stimuli that will also evoke the requisite phenomenology: one day we may have the equivalent of Gabors for studying complex visual appearance.

Predicting human performance in fundamental visual tasks with natural stimuli

Speaker: Johannes Burge, Department of Psychology, Neuroscience Graduate Group, University of Pennsylvania

Understanding how vision works under natural conditions is a fundamental goal of vision science. Vision research has made enormous progress toward this goal by probing visual function with artificial stimuli. However, evidence is mounting that artificial stimuli may not be fully up to the task. The field is full of computational models—from retina to behavior—that beautifully account for performance with artificial stimuli, but that generalize poorly to arbitrary natural stimuli. On the other hand, research with natural stimuli is often criticized on the grounds that natural signals are too complex and insufficiently controlled for results to be interpretable. I will describe recent efforts to develop methods for using natural stimuli without sacrificing computational and experimental rigor. Specifically, I will discuss how we use natural stimuli, techniques for dimensionality reduction, and ideal observer analysis to tightly predict human estimation and discrimination performance in three tasks related to depth perception: binocular disparity estimation, speed estimation, and motion through depth estimation. Interestingly, the optimal processing rules for processing natural stimuli also predict human performance with classic artificial stimuli. We conclude that properly controlled studies with natural stimuli can complement studies with artificial stimuli, perhaps contributing insights that more traditional approaches cannot.

Natural behaviour with artificial stimuli: probing praying mantis vision

Speaker: Jenny Read; Newcastle University, Institute of Neuroscience

Additional Authors: Dr Vivek Nityananda, Dr Ghaith Tarawneh, Dr Ronny Rosner, Ms Lisa Jones, Newcastle University, Institute of Neuroscience

My lab is working to uncover the neural circuitry supporting stereoscopic vision in the praying mantis, the only invertebrate known to possess this ability. Mantises catch their prey by striking out with their spiked forelimbs. This strike is released only when prey is perceived to be at the appropriate distance, so provides an extremely convenient way of probing the insects' depth perception. Other behaviours, such as tracking, saccades and optomotor response, also inform us about mantis vision. Because we are using natural rather than trained behaviours, our stimuli have to be naturalistic enough to elicit these responses. Yet as we begin the study of mantis stereopsis, clear answers to our scientific questions are often best obtained by artificial or indeed impossible stimuli. For example, using artificial "cyclopean" stimuli, where objects are defined purely by disparity, would enable us to be sure that the mantis' responses are mediated totally by disparity and not by other cues. Using anti-correlated stereograms, which never occur in nature, could help us understand whether mantis stereopsis uses cross-correlation between the two eyes' images. Accordingly, my lab is navigating a compromise between these extremes. We are seeking stimuli which are naturalistic enough to drive natural behaviour, while artificial enough to provide cleanly-interpretible answers our research questions – although we do sometimes end up with stimuli which are naturalistic enough to present confounds, and artificial enough to lack ecological validity. I will discuss the pros and cons, and aim to convince you we are making progress despite the pitfalls.

Natural scene statistics and estimation of shape and reflectance

Speaker: Wendy Adams; University of Southampton

Additional Authors: Erich W. Graf, University of Southampton, Southampton, UK; James H. Elder, York University, Canada

A major function of the visual system is to estimate the shape and reflectance of objects and surfaces from the image. Evidence from both human and computer vision suggests that solutions to this problem involve exploiting prior probability distributions over shape, reflectance and illumination. In an optimal system, these priors would reflect the statistics of our world. To allow a better understanding of the statistics of our environment, and how these statistics shape human perception, we have developed the Southampton-York Natural Scenes (SYNS) public dataset. The dataset includes scene samples from a wide variety of indoor and outdoor scene categories. Each scene sample consists of (i) 3D laser range (LiDAR) data over a nearly spherical field of view, co-registered with (ii) spherical high dynamic range imagery, and (iii) a panorama of stereo image pairs. These data are publicly available at https://syns.soton.ac.uk/. I will discuss a number of challenges that we have addressed in the course of this project, including: 1) geographic sampling strategy, 2) scale selection for surface analysis, 3) relating scene measurements to human perception. I will also discuss future work and potential applications.

S2 - Boundaries in Spatial Navigation and Visual Scene Perception

Friday, May 13, 12:00 - 2:00 pm, Pavilion

Organizers: Soojin Park, Johns Hopkins University and Sang Ah Lee, University of Trento

Presenters: Sang Ah Lee, Joshua B Julian, Nathaniel J. Killian, Tom Hartley, Soojin Park, Katrina Ferrara

The ability to navigate in the world using vision is intrinsically tied to the ability to analyze spatial relationship within a scene. For the past few decades, navigation researchers have shown that humans and nonhuman animals alike compute locations by using a spontaneously encoded geometry of the 3D environmental boundary layouts. This finding has been supported by neural evidence showing boundary-specific inputs to hippocampal place-mapping. More recently, researchers in visual scene perception have shown that boundaries not only play an important role in defining geometry for spatial navigation, but also in visual scene perception. How are boundary representations in scene perception related to those in navigation? What are the defining features of boundaries, and what are their neural correlates? The aim of this symposium is to bridge research from various subfields of cognitive science to discuss the specific role of boundaries in the processing of spatial information and to converge on a coherent theoretical framework for studying visual representations of boundaries. To achieve this, we have brought together an interdisciplinary group of speakers to present studies of boundary representations on a broad range of subject populations, from rodents, to primates, to individuals with genetic disorders, using various experimental methods (developmental, behavioral, fMRI, TMS, single-cell and population coding). The theoretical flow of the symposium will start with behavioral studies showing specificity and primacy of boundaries in spatial navigation and memory in both humans and a wide range of nonhuman vertebrates. Then, we will ask whether neural representations of boundary geometry can be derived from visual input, as opposed to active navigation, using primate's saccadic eye gaze and human scene perception. Lastly, we will present evidence of spatial impairment marked by a dysfunction of boundary-processing mechanisms in Williams Syndrome. We believe that this symposium will be of great interest to VSS attendees for the following reasons: First, these convergent findings from independent research approaches to spatial representations and their neural correlates will make a powerful impact on theories of spatial information processing, from visual perception to hippocampal spatial mapping. Second, a better understanding of boundary geometry can broadly inform any research that involves visuo-spatial representations, such as studies on spatial perspective and saccadic eye movements. Finally, the methodological breadth of this symposium, and its aim to integrate them to a coherent picture will provide a new perspective on the power of multidisciplinary research in visual and cognitive sciences.

Boundaries in space: A comparative approach

Speaker: Sang Ah Lee; Center for Mind/Brain Sciences, University of Trento

Spatial navigation provides a unique window into the evolutionary and developmental origins of complex behaviors and memory, due to its richness in representation and computation, its striking similarities between distantly related species, its neural specificity, and its transformation across human development. Environmental boundaries have been shown to play a crucial role in both neural and behavioral studies of spatial representation. In this talk, I will discuss evidence on boundary coding on three different levels: First, I will share my findings showing the primacy and specificity of visual representations of 3D environmental "boundaries" in early spatial navigation in children. Second, I will argue that the cognitive mechanisms underlying boundary representations are shared and widespread across the phylogenetic tree. Finally, I will bring together insights gathered from behavioral findings to investigate the neural underpinnings of boundary coding. From the firing of neurons in a navigating rat's brain, to a child's developing understanding of abstract space, I will argue that boundary representation is a fundamental, evolutionarily ancient ability that serves as a basis for spatial cognition and behavior.

Mechanisms for encoding navigational boundaries in the mammalian brain

Speaker: Joshua B Julian; Department of Psychology, University of Pennsylvania

Authors: Alex T Keinath, Department of Psychology, University of Pennsylvania; Jack Ryan, Department of Psychology, University of Pennsylvania; Roy H Hamilton, Department of Neurology, University of Pennsylvania; Isabel A Muzzio, Department of Biology, University of Texas: San Antonio; Russell A Epstein, Department of Psychology, University of Pennsylvania

Thirty years of research suggests that environmental boundaries exert powerful control over navigational behavior, often to the exclusion of other navigationally-relevant cues, such as objects or visual surface textures. Here we present findings from experiments in mice and humans demonstrating the existence of specialized mechanisms for processing boundaries during navigation. In the first study, we examined the navigational behavior of disoriented mice trained to locate rewards in two chambers with geometrically identical boundaries, distinguishable based on the visual textures along one wall. We observed that although visual textures were used to identify the chambers, those very same cues were not used to disambiguate facing directions within a chamber. Rather, recovery of facing directions relied exclusively on boundary geometry. These results provide evidence for dissociable processes for representing boundaries and other visual cues. In a second line of work, we tested whether the human visual system contains neural regions specialized for processing of boundaries. Specifically, we tested the prediction that the Occipital Place Area (OPA) might play a critical role in boundary-based navigation, by extracting boundary information from visual scenes. To do so, we used transcranial magnetic stimulation (TMS) to interrupt processing in the OPA during a navigation task that required participants to learn object locations relative to boundaries and non-boundary cues. We found that TMS of the OPA impaired learning of locations relative to boundaries, but not relative to landmark objects or large-scale visual textures. Taken together, these results provide evidence for dedicated neural circuitry for representing boundary information.

Neuronal representation of visual borders in the primate entorhinal cortex

Speaker: Nathaniel J. Killian; Department of Neurosurgery, Massachusetts General Hospital-Harvard Medical School

Authors: Elizabeth A Buffalo, Department of Physiology and Biophysics, University of Washington

The entorhinal cortex (EC) is critical to the formation of memories for complex visual relationships. Thus we might expect that EC neurons encode visual scenes within a consistent spatial framework to facilitate associations between items and the places where they are encountered. In particular, encoding of visual borders could provide a means to anchor visual scene information in allocentric coordinates. Studies of the rodent EC have revealed neurons that represent location, heading, and borders when an animal is exploring an environment. Because of interspecies differences in vision and exploratory behavior, we reasoned that the primate EC may represent visual space in a manner analogous to the rodent EC, but without requiring physical visits to particular places or items. We recorded activity of EC neurons in non-human primates (Macaca mulatta) that were head-fixed and freely viewing novel photographs presented in a fixed external reference frame. We identified visual border cells, neurons that had increased firing rate when gaze was close to one or more image borders. Border cells were co-localized with neurons that represented visual space in a grid-like manner and with neurons that encoded the angular direction of saccadic eye movements. As a population, primate EC neurons appear to represent gaze location, gaze movement direction, and scene boundaries. These spatial representations were detected in the presence of changing visual content, suggesting that the EC provides a consistent spatial framework for encoding visual experiences.

Investigating cortical encoding of visual parameters relevant to spatial cognition and environmental geometry in humans.

Speaker: Tom Hartley; Department of Psychology, University of York, UK

Authors: David Watson, Department of Psychology, University of York, UK; Tim Andrews, Department of Psychology, University of York, UK

Studies of firing properties of cells in the rodent hippocampal formation indicate an important role for "boundary cells" in anchoring the allocentric firing fields of place and grid cells. To understand how spatial variables such as the distance to local boundaries might be derived from visual input in humans, we are investigating links between the statistical properties of natural scenes and patterns of neural response in scene selective visual cortex. In our latest work we used a data-driven analysis to select clusters of natural scenes from a large database, solely on the basis of their image properties. Although these visually-defined clusters did not correspond to typical experimenter-defined categories used in earlier work, we found they elicited distinct and reliable patterns of neural response in parahippocampal cortex, and that the relative similarity of the response patterns was better explained in terms of low-level visual properties of the images than by local semantic information. Our results suggest that human parahippocampal cortex encodes visual parameters (including properties relevant to environmental geometry). Our approach opens the way to isolating these parameters and investigating their relationship to spatial variables.

Complementary neural representation of scene boundaries

Speaker: Soojin Park; Department of Cognitive Science, Johns Hopkins University

Authors: Katrina Ferrara, Center for Brain Plasticity and Recovery, Georgetown University

Environmental boundaries play a critical role in defining spatial geometry and restrict our movement within an environment. Developmental research with 4-year-olds shows that children are able to reorient themselves by the geometry of a curb that is only 2 cm high, but fail to do so when the curb boundary is replaced by a flat mat on the floor (Lee & Spelke, 2011). In this talk, we will present evidence that such fine-grained sensitivity to a 3D boundary cue is represented in visual scene processing regions of the brain, parahippocampal place area (PPA) and retrosplenial cortex (RSC). First, we will present univariate and multivoxel pattern data from both regions to suggest that they play complementary roles in the representation of boundary cues. The PPA shows disproportionately strong sensitivity to the presence of a slight vertical boundary, demonstrating a neural signature that corresponds to children's behavioral sensitivity to slight 3D vertical cues (i.e., the curb boundary). RSC did not display this sensitivity. We will argue that this sensitivity does not simply reflect low-level image differences across conditions. Second, we investigate the nature of boundary representation in RSC by parametrically varying the height of boundaries in the vertical dimension. We find that RSC's response matches a behavioral categorical decision point for the boundary's functional affordance (e.g., whether the boundary limits the viewer's potential navigation or not). Collectively, this research serves to highlight boundary structure as a key component of space that is represented in qualitatively different ways across two scene-selective brain regions.

Neural and behavioral sensitivity to boundary cues in Williams syndrome

Speaker: Katrina Ferrara; Center for Brain Plasticity and Recovery, Georgetown University

Authors: Barbara Landau, Department of Cognitive Science, Johns Hopkins University; Soojin Park, Department of Cognitive Science, Johns Hopkins University

Boundaries are fundamental features that define a scene and contribute to its geometric shape. Our previous research using fMRI demonstrates a distinct sensitivity to the presence of vertical boundaries in scene representation by the parahippocampal place area (PPA) in healthy adults (Ferrara & Park, 2014). In the present research, we show that this sensitivity to boundaries is impaired by genetic deficit. Studying populations with spatial disorders can provide insight to potential brain/behavior links that may be difficult to detect in healthy adults. We couple behavioral and neuroimaging methods to study individuals with Williams syndrome (WS), a disorder characterized by the deletion of 25 genes and severe impairment in a range of spatial functions. When both humans and animals are disoriented in a rectangular space, they are able to reorient themselves by metric information conveyed by the enclosure's boundaries (e.g., long wall vs. short wall). Using this reorientation process as a measure, we find that individuals with WS are unable to reorient by a small boundary cue, in stark contrast to the behavior of typically developing (TD) children (Lee & Spelke, 2011). Using fMRI, we find a linked neural pattern in that the WS PPA does not detect the presence of a small boundary within a scene. Taken together, these results demonstrate that atypical patterns of reorientation correspond with less fine-grained representation of boundaries at the neural level in WS. This suggests that sensitivity to the geometry of boundaries is one of the core impairments that underlies the WS reorientation deficit.

S3 - What do deep neural networks tell us about biological vision?

Friday, May 13, 2:30 - 4:30 pm, Talk Room 1-2

Organizer: Radoslaw Martin Cichy, Department of Psychology and Education, Free University Berlin, Berlin, Germany

Presenters: Kendrick Kay, Seyed-Mahdi Khaligh-Razavi, Daniel Yamins, Radoslaw Martin Cichy, Tomoyasu Horikawa, Kandan Ramakrishnan

Visual cognition in humans is mediated by complex, hierarchical, multi-stage processing of visual information, propagated rapidly as neural activity in a distributed network of cortical regions. Understanding visual cognition in cortex thus requires a predictive and quantitative model that captures the complexity of the underlying spatio-temporal dynamics and explains human behavior. Very recently, brain-inspired deep neural networks (DNNs) have taken center stage as an artificial computational model for understanding human visual cognition. A major reason for their emerging dominance is that DNNs perform near human-level performance on tasks such as object recognition (Russakovsky et al., 2014). While DNNs were initially developed by computer scientists to solve engineering problems, research comparing visual representations in DNNs and primate brains have found a striking correspondence, creating excitement in vision research (Kriegeskorte 2015, Ann Rev Vis, Keynote VSS 2014 Bruno Olshausen; Jones 2014; Nature). The aim of this symposium is three-fold: One aim is to describe cutting-edge research efforts that use DNNs to understand human visual cognition. A second aim is to establish which results reproduce across studies and thus create common ground for further research. A third aim is to provide a venue for critical discussion of the theoretical implications of the results. To introduce and frame the debate for a wide audience, Kendrick Kay will start with thorough introduction to the DNN approach in the beginning and formulate questions and challenges to which the individual speakers will respond in their talks. The individual talks will report on recent DNN-related biological vision research. The talks will cover a wide range of results: brain data recorded in different species (human, monkey), with different techniques (electrophysiology, fMRI, M/EEG), for static as well as movie stimuli, using a wide range of analysis techniques (decoding and encoding models, representational similarity analysis). Major questions addressed will be: what do DNNs tell us about visual processing in the brain? What is the theoretical impact of finding a correspondence between DNNs and representations in human brains? Do these insights extend to visual cognition such as imagery? What analysis techniques and methods are available to relate DNNs to human brain function? What novel insights can be gained from comparison of DNNs to human brains? What effects reproduce across studies? A final 20-min open discussion between speakers and the audience will close the symposium, encouraging discussion on what aims the DNN approach has reached already, where it fails, what future challenges lie ahead, and how to tackle them. As DNNs address visual processing across low to mid- to high-level vision, we believe this symposium will be of interest to a broad audience, including students, postdocs and faculty. This symposium is a grass-roots first-author-based effort, bringing together junior researchers from around the world (US, Germany, Netherlands, and Japan).

What are deep neural networks and what are they good for?

Speaker: Kendrick Kay; Center for Magnetic Resonance Research, University of Minnesota, Twin Cities

In this talk, I will provide a brief introduction to deep neural networks (DNN) and discuss their usefulness with respect to modeling and understanding visual processing in the brain. To assess the potential benefits of DNN models, it is important to step back and consider generally the purpose of computational modeling and how computational models and experimental data should be integrated. Is the only goal to match experimental data? Or should we derive understanding from computational models? What kinds of information can be derived from a computational model that cannot be derived through simpler analyses? Given that DNN models can be quite complex, it is also important to consider how to interpret these models. Is it possible to identify the key feature of a DNN model that is responsible for a specific experimental effect? Is it useful to perform 'in silico' experiments with a DNN model? Should we should strive to perform meta-modeling, that is, developing a (simple) model of a (complex DNN) model in order to help understand the latter? I will discuss these and related issues in the context of DNN models and compare DNN modeling to an alternative modeling approach that I have pursued in past research.

Mixing deep neural network features to explain brain representations

Speaker: Seyed-Mahdi Khaligh-Razavi; CSAIL, MIT, MA, USA

Authors: Linda Henriksson, Department of Neuroscience and Biomedical Engineering, Aalto University, Aalto, Finland Kendrick Kay, Center for Magnetic Resonance Research, University of Minnesota, Twin Cities Nikolaus Kriegeskorte, MRC-CBU, University of Cambridge, UK

Higher visual areas present a difficult explanatory challenge and can be better studied by considering the transformation of representations across the stages of the visual hierarchy from lower- to higher-level visual areas. We investigated the progress of visual information through the hierarchy of visual cortex by comparing the representational geometry of several brain regions with a wide range of object-vision models, ranging from unsupervised to supervised, and from shallow to deep models. The shallow unsupervised models tended to have higher correlations with early visual areas; and the deep supervised models were more correlated with higher visual areas. We also presented a new framework for assessing the pattern-similarity of models with brain areas, mixed representational similarity analysis (RSA), which bridges the gap between RSA and voxel-receptive-field modelling, both of which have been used separately but not in combination in previous studies (Kriegeskorte et al., 2008a; Nili et al., 2014; Khaligh-Razavi and Kriegeskorte, 2014; Kay et al., 2008, 2013). Using mixed RSA, we evaluated the performance of many models and several brain areas. We show that higher visual representations (i.e. lateral occipital region, inferior temporal cortex) were best explained by the higher layers of a deep convolutional network after appropriate mixing and weighting of its feature set. This shows that deep neural network features form the essential basis for explaining the representational geometry of higher visual areas.

Using DNNs To Compare Visual and Auditory Cortex

Speaker: Daniel Yamins; Department of Brain and Cognitive Sciences, MIT, MA, USA

Authors: Alex Kell, Department of Brain and Cognitive Sciences, MIT, MA, USA

A slew of recent studies have shown how deep neural networks (DNNs) optimized for visual tasks make effective models of neural response patterns in the ventral visual stream. Analogous results have also been discovered in auditory cortex, where optimizing DNNs for speech-recognition tasks has produced quantitatively accurate models of neural response patterns in auditory cortex. The existence of computational models within the same architectural class for two apparently very different sensory representations begs several intriguing questions: (1) to what extent do visual models predict auditory response patterns, and to what extent to do auditory models predict visual response patterns? (2) In what ways are the vision and auditory models models similar, and what ways do they diverge? (3) What do the answers to the above questions tell us about the relationships between the natural statistics of these two sensory modalities — and the underlying generative processes behind them? I'll describe several quantitative and qualitative modeling results, involving electrophysiology data from macaques and fMRI data from humans, that shed some initial light on these questions.

Deep Neural Networks explain spatio-temporal dynamics of visual scene and object processing

Speaker: Radoslaw Martin Cichy; Department of Psychology and Education, Free University Berlin, Berlin, Germany

Authors: Aditya Khosla, CSAIL, MIT, MA, USA Dimitrios Pantazis, McGovern Institute of Brain and Cognitive Sciences, MIT, MA, USA Antonio Torralba, CSAIL, MIT, MA, USA Aude Oliva, CSAIL, MIT, MA, USA

Understanding visual cognition means knowing where and when what is happening in the brain when we see. To address these questions in a common framework we combined deep neural networks (DNNs) with fMRI and MEG by representational similarity analysis. We will present results from two studies. The first study investigated the spatio-temporal neural dynamics during visual object recognition. Combining DNNs with fMRI, we showed that DNNs predicted a spatial hierarchy of visual representations in both the ventral, and the dorsal visual stream. Combining DNNs with MEG, we showed that DNNs predicted a temporal hierarchy with which visual representations emerged. This indicates that 1) DNNs predict the hierarchy of visual brain dynamics in space and time, and 2) provide novel evidence for object representations in parietal cortex. The second study investigated how abstract visual properties, such as scene size, emerge in the human brain in time. First, we identified an electrophysiological marker of scene size processing using MEG. Then, to explain how scene size representations might emerge in the brain, we trained a DNN on scene categorization. Representations of scene size emerged naturally in the DNN without it ever being trained to do so, and DNN accounted for scene size representations in the human brain. This indicates 1) that DNNs are a promising model for the emergence of abstract visual properties representations in the human brain, and 2) gives rise to the idea that the cortical architecture in human visual cortex is the result of task constraints imposed by visual tasks.

Generic decoding of seen and imagined objects using features of deep neural networks

Speaker: Tomoyasu Horikawa; Computational Neuroscience Laboratories, ATR, Kyoto, Japan

Authors: Yukiyasu Kamitani; Graduate School of Informatics, Kyoto University, Kyoto, Japan

Object recognition is a key function in both human and machine vision. Recent studies support that a deep neural network (DNN) can be a good proxy for the hierarchically structured feed-forward visual system for object recognition. While brain decoding enabled the prediction of mental contents represented in our brain, the prediction is limited to training examples. Here, we present a decoding approach for arbitrary objects seen or imagined by subjects by employing DNNs and a large image database. We assume that an object category is represented by a set of features rendered invariant through hierarchical processing, and show that visual features can be predicted from fMRI patterns and that greater accuracy is achieved for low/high-level features with lower/higher-level visual areas, respectively. Furthermore, visual feature vectors predicted by stimulus-trained decoders can be used to identify seen and imagined objects (extending beyond decoder training) from a set of computed features for numerous objects. Successful object identification for imagery-induced brain activity suggests that feature-level representations elicited in visual perception may also be used for top-down visual imagery. Our results demonstrate a tight link between the cortical hierarchy and the levels of DNNs and its utility for brain-based information retrieval. Because our approach enabled us to predict arbitrary object categories seen or imagined by subjects without pre-specifying target categories, we may be able to apply our method to decode the contents of dreaming. These results contribute to a better understanding of the neural representations of the hierarchical visual system during perception and mental imagery.

Mapping human visual representations by deep neural networks

Speaker: Kandan Ramakrishnan; Intelligent Sensory Information Systems, UvA, Netherlands

Authors: H.Steven Scholte; Department of Psychology, Brain and Cognition, UvA, Netherlands, Arnold Smeulders, Intelligent Sensory Information Systems, UvA, Netherlands, Sennay Ghebreab; Intelligent Sensory Information Systems, UvA, Netherlands

A number of recent studies have shown that deep neural networks (DNN) map to the human visual hierarchy. However, based on a large number of subjects and accounting for the correlations between DNN layers, we show that there is no one-to-one mapping of DNN layers to the human visual system. This suggests that the depth of DNN, which is also critical to its impressive performance in object recognition, has to be investigated for its role in explaining brain responses. On the basis of EEG data collected from a large set of natural images we analyzed different DNN architectures – a 7 layer, 16 layer and a 22 layer DNN network using weibull distribution for the representations at each layer. We find that the DNN architectures reveal temporal dynamics of object recognition, with early layers driving responses earlier in time and higher layers driving the responses later in time. Surprisingly the layers from the different architectures explain brain responses to a similar degree. However, by combining the representations of the DNN layers we observe that in the higher brain areas we explain more brain activity. This suggests that the higher areas in the brain are composed of multiple non-linearities that are not captured by the individual DNN layers. Overall, while DNNs form a highly promising model to map the human visual hierarchy, the representations in the human brain go beyond the simple one-to-one mapping of the DNN layers to the human visual hierarchy.

S4 - What can we learn from #TheDress – in search for an explanation

Friday, May 13, 2:30 - 4:30 pm, Pavilion

Organizer: Annette Werner, Institute for Ophthalmic Research, Tübingen University

Presenters: Annette Werner, Anya Hurlbert, Christoph Witzel, Keiji Uchikawa, Bevil Conway, Lara Schlaffke

Few topics in colour research have generated so much interest in the science community and public alike, as the recent #TheDress. The phenomenon refers to the observation that observers cannot agree on colour names for a dress seen in a particular photograph, i.e. colour judgements fall into at least two categories, namely blue&black and white&gold. Although individual differences in colour perception are well known, this phenomenon is still unprecendented since it uncovers a surprising ambiguity in colour vision – surprising because our visual brain was thought to reconstruct surface colour so successfully that it is experienced by the naive observer as an inherent property of objects. Understanding the origin of the perceptual dichotomy of #TheDress is therefore important not only in the context of the phenomenon itself but also for our comprehension of the neural computations of colour in general. Since it's discovery, a number of hypotheses have been put forward, in order to explain the phenomenon; these

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include individual differences in peripheral or sensory properties such as variations in the entopic filters of the eye, or in the spectral sensitivities of the chromatic pathways; „high end" explanations concern differences at cognitive stages, e.g. regarding the interpretation of the lightfield in a scene, or the use of priors for estimating the illuminant or the surface colour. The ambiguity in case of #TheDress may arise because of the peculiar distribution of surface colours in the photo and the lack of further information in the background. The symposium shall gather the actual experimental evidence, and provide a profound basis for the discussion and evaluation of existing and novel hypotheses. The topic will be introduced by the organizer and concluded by a general discussion of the experimental findings of all presentations. Because of the wide spread interest for the topic of #TheDress and it's general importance for colour vision, we expect a large VSS audience, including students, postdocs, and senior scientists from all fields in vision research.

The #Dress phenomenon – an empirical investigation into the role of the background

Speaker: Annette Werner; Institute for Ophthalmic Research, Tübingen University, Germany

Authors: Alisa Schmidt, Institute for Ophthalmic Research, Tübingen University, Germany

The #TheDress phenomenon refers to a dichotomy in colour perception, which is specific to the foto of a blue&black dress, namely that most observers judge its colours as either blue/black or white/gold. Hypotheses explaining the phenomenon include individual variations of information pocessing at sensory as well as cognitive stages. In particular it has been proposed that the lack of/ambiguity in background information leads observers to different conclusions about the illuminant and the light field. We will present result of matching experiments involving the presentations of the real blue/black dress, mounted on differently colour backgrounds and under the illuminations of two slide projectors, thereby mimicking the ambiguity of the photo. The results identify the use of information from the background as a source for the observed individual differences. The results are discussed in the context of the aquisition, the content and the use of "scene knowledge".

Is that really #thedress? Individual variations in colour constancy for real illuminations and objects

Speaker: Anya Hurlbert; Institute of Neuroscience, University of Newcastle upon Tyne, UK

Authors: Stacey Aston, Bradley Pearce: Institute of Neuroscience, University of Newcastle upon Tyne, UK

One popular explanation for the individual variation in reported colours of #thedress is an individual variation in the underlying colour constancy mechanisms, which cause differences in the illumination estimated and subsequently discounted. Those who see the dress as 'white/gold' are discounting a 'blueish' illumination, while those who see it as 'blue/black' are discounting a 'yellowish' illumination. These underlying differences are brought into relief by the ambiguity of the original photograph. If this explanation holds, then similarly striking individual differences in colour constancy might also be visible in colour matching and naming tasks using real objects under real illuminations, and the conditions under which they are elicited may help to explain the particular power of #thedress. I will discuss results of colour constancy measurements using the real dress, which is almost universally reported to be 'blue/black' when illuminated by neutral, broad-band light, yet elicits similar variability in colour naming to the original photograph, across observers within certain illumination conditions, most pronouncedly for ambiguous and/or atypical illuminations. Colour constancy by both naming and matching is in fact relatively poor for the real dress and other unfamiliar items of clothing, but better for "blueish" illuminations than other chromatic illuminations or ambiguous multiple-source illuminations. Overall, individual variations in colour constancy are significant, and depend on age and other individual factors.

Variation of subjective white-points along the daylight axis and the colour of the dress

Speaker: Christoph Witzel; Laboratoire Psychologie de la Perception, University Paris Descartes, France

Authors: Sophie Wuerger, University of Liverpool, UK, Anya Hurlbert, Institute of Neuroscience, University of Newcastle upon Tyne, UK

We review the evidence, from different data sets collected under different viewing conditions, illumination sources, and measurement protocols, for intra- and interobserver variability in "generic subjective white-point" settings along the daylight locus. By "generic subjective white-point" we mean the subjective white-point independent of the specific context. We specifically examine the evidence across all datasets for a "blue" bias in subjective white-points (i.e. increased variability or reduced sensitivity in the bluish direction). We compare the extent of daylight-locus variability generally and variability in the "bluish" direction specifically of subjective white points across these data sets (for different luminance levels and light source types). The variability in subjective white-point may correspond to subjective "priors" on illumination chromaticity. In turn, individual differences in assumptions about the specific illumination chromaticity on "the dress" (in the recent internet phenomenon) is widely thought to explain the individual differences in reported dress colours. We therefore compare the variability in generic white-point settings collated across these datasets with the variability in generic white-point settings made in the specific context of the dress (Witzel and O'Regan, ECVP 2015). Our analysis suggests that (1) there is an overall "blue" bias in generic subjective white-point settings and (2) the variability in generic subjective white-point settings is insufficient to explain the variability in reported dress colours. Instead, the perceived colors of the dress depend on assumptions about the illumination that are specific to that particular photo of the dress.

Prediction for individual differences in appearance of the "dress" by the optimal color hypothesis

Speaker: Keiji Uchikawa; Department of Information Processing, Tokyo Institute of Technology, Japan

Authors: Takuma Morimoto, Tomohisa Matsumoto; Department of Information Processing, Tokyo Institute of Technology, Japan

When luminances of pixels in the blue-black/white-gold "dress" image were plotted on the MacLeod-Boynton chromaticity diagram they appeared to have two clusters. They corresponded to the white/blue and the gold/black parts. The approach we took to solve the dress problem was to apply our optimal color hypothesis to estimate an illuminant in the dress image. In the optimal color hypothesis, the visual system picks the optimal color distribution, which best fits to the scene luminance distribution. The peak of the best-fit optimal color distribution corresponds to the illuminant chromaticity. We tried to find the best-fit optimal color distribution to the dress color distribution. When illuminant level was assumed to be low, the best-fit color temperature was high (20000K). Under this dark-blue illuminant the dress colors should look white-gold. When illuminant level was assumed to be high, the lower temperature optimal color distribution (5000K) fitted the best. Under this bright-white illuminant the dress colors should appear blue-black. Thus, for the dress image the best-fit optimal color distribution changed depending on illuminant intensity. This dual-stable illuminant estimations may cause the individual difference in appearance of the dress. If you choose a bright (or dark) illuminant the dress appears blue-black (or white-gold). When the chromaticity of the dress was rotated in 180 degree in the chromaticity diagram it appeared blue-gold without individual difference. In this case the optimal color hypothesis predicted an illuminant with almost no ambiguity. We tested individual differences using simple patterns in experiments. The results supported our prediction.

Mechanisms of color perception and cognition covered by #thedress

Speaker: Bevil Conway; Department of Brain and Cognitive Sciences, MIT, Cambridge MA, USA

Authors: Rosa Lafer-Sousa, Katherine Hermann

Color is notoriously ambiguous—many color illusions exist—but until now it has been thought that all people with normal color vision experience color illusions the same way. How does the visual system resolve color ambiguity? Here, we present work that addresses this question by quantifying people's perception of a particularly ambiguous image, 'the dress' photograph. The colors of the individual pixels in the photograph when viewed in isolation are light-blue or brown, but popular accounts suggest the dress appears either white/gold or blue/black. We tested more than 1400 people, both on-line and under controlled laboratory conditions. Subjects first completed the sentence: "this is a ___and___dress". Then they performed a color-matching experiment that did not depend on language. Surprisingly, the results uncovered three groups of subjects: white/gold observers, blue/black observers and blue/brown observers. Our findings show that the brain resolves ambiguity in 'the dress' into one of three stable states; a minority of people switched which colors they saw (~11%). It is clear that what we see depends on both retinal stimulation and internal knowledge about the world. Cases of multi-stability such as 'the dress' provide a rare opportunity to investigate this interplay. In particular, we go on to demonstrate that 'the dress' photograph can be used as a tool to discover that skin reflectance is a particularly important implicit cue used by the brain to estimate the color of the light source, to resolve color ambiguity, shedding light on the role of high-level cues in color perception.

The Brain's Dress Code: How The Dress allows to decode the neuronal pathway of an optical illusion

Speaker: Lara Schlaffke; Department of Neurology, BG University Hospital Bergmannsheil, Bochum, Germany

Authors: Anne Golisch, Lauren M. Haag, Melanie Lenz, Stefanie Heba, Silke Lissek, Tobias Schmidt-Wilcke, Ulf T. Eysel, Martin Tegenthoff

Optical illusions have broadened our understanding of the brains role in visual perception 1–3. A modern day optical illusion emerged from a posted photo of a striped dress, which some perceived as white and gold and others as blue and black. Theories on the differences have been proposed and included e.g. colour constancy, contextual integration, and the principle of ambiguous forms4, however no consensus has yet been reached. The fact that one group sees a white/gold dress, instead of the actual blue/black dress, provides a control and therefore a unique opportunity in vision research, where two groups perceive the same object differently. Using functional magnetic resonance imaging (fMRI) we can identify human brain regions that are involved in this optical illusion concerning colour perception and investigate the neural correlates that underlie the observed differences. Furthermore open questions in visual neuroscience concerning the computation of complex visual scenes can be addressed. Here we show, using fMRI, that those who perceive The Dress as white/gold (n=14) have higher activation in response to The Dress in brain regions critically involved in visual processing and conflict management (V2, V4, as well as frontal and parietal brain areas), as compared to those who perceive The Dress as blue/black (n=14). These results are consistent with the theory of top-down modulation5 and extend the Retinex theory6 to include differing strategies the brain uses to form a coherent representation of the world around us. This provides a fundamental building block to study interindividual differences in visual processing.

S5 - ARVO@VSS: Information processing in a simple network: What the humble retina tells the brain.

Friday, May 13, 5:00 - 7:00 pm, Talk Room 1-2

Organizers: Scott Nawy, PhD, University of Nebraska Medical Center and Anthony Norcia, Stanford University

Presenters: Greg Field, Michael Crair, William Guido, Wei Wei

This year's biennial ARVO at VSS symposium features a selection of recent work on circuit-level analyses of retinal, thalamic and collicular systems that are relevant to understanding of cortical mechanisms of vision. The speakers deploy a range of state-of-the art methods that bring an unprecedented level of precision to dissecting these important visual circuits.

Circuitry and computation in the mammalian retina

Speaker: Greg Field; USC

The mammalian retina is composed of ~80 distinct neuronal cell types. These neurons work in concert to parcel visual information into ~30 different RGC types, each of which transmits a different message about the visual scene to the brain. I will describe ongoing work in my lab to define the functional role of different cell types in the mammalian retina via the combination of large-scale multi-electrode array recordings and chemogenetic manipulation of genetically defined cell types. This combination of approaches is revealing the specialized roles played by different cell types to encode visual scenes for perception and behavior.

Retinal activity guides visual circuit development prior to sensory experience

Speaker: Michael C. Crair; Yale

Classic models emphasize an important role of sensory experience in the development of visual circuits in the mammalian brain. However, recent evidence indicates that fundamental features of visual circuits in the thalamus, cortex and superior colliculus emerge prior to the emergence of form vision. I will summarize our latest experiments that use in vivo optical imaging techniques and molecular-genetic manipulations in mice to demonstrate that spontaneous retinal activity, generated prior to vision, plays an essential role in sculpting the development of visual circuits in the mammalian brain.

Dissecting circuits in the mouse visual thalamus

Speaker: William Guido; University of Louisville

The contemporary view of the dorsal lateral geniculate nucleus (dLGN) of thalamus is that of a visual relay, where the gain of signal transmission is modulated by a diverse set of inputs that arise from non-retinal sources. I will highlight our recent studies in the mouse, an animal model that provides unprecedented access into the circuitry underlying these operations.

Neural mechanisms of direction selectivity in the retina

Speaker: Wei Wei; Department of Neurobiology, The University of Chicago

Authors: Qiang Chen, David Koren and Wei Wei, Department of Neurobiology, The University of Chicago

The direction selective circuit in the retina computes motion directions and conveys this information to higher brain areas via the spiking activity of direction selective ganglion cells. While multiple synaptic mechanisms have been implicated in the generation of direction selectivity in the retina, it is unclear how individual mechanism modulates the firing patterns of direction selective ganglion cells. Here, we aim to unambiguously differentiate the contributions of distinct circuit components to direction selectivity by loss-of-function studies using genetic, electrophysiological and functional imaging methods. Our results highlight the concerted actions of synaptic and cell-intrinsic mechanisms required for robust direction selectivity in the retina, and provide critical insights into how patterned excitation and inhibition collectively implement sensory processing in the brain.

S6 - The parietal cortex in vision, cognition, and action

Friday, May 13, 5:00 - 7:00 pm, Pavilion

Organizers: Yaoda Xu, Harvard University and David Freedman, University of Chicago

Presenters: Sabine Kastner, Yaoda Xu, Jacqueline Gottlieb, David Freedman, Peter Janssen, Melvyn Goodale

The primate parietal cortex has been associated with a diverse set of operations. Early evidence has highlighted the role of this brain region in spatial, attention, and action related processing. More recent evidence, however, has suggests a role for parietal cortex in non-spatial and cognitive functions such as object representation, categorization, short-term memory, number processing and decision making. How should we understand its function, given the wide array of sensory, cognitive and motor signals found to be encoded in parietal areas? Are there functionally dissociable regions within the primate parietal cortex, each participating in distinct functions? Or are the same parietal regions involved in multiple functions? Is it possible to form a unified account of parietal cortex's role in perception, action and cognition? In this symposium, by bringing together researchers from monkey neurophysiology and human brain imaging, we will first ask the speakers to present our current understanding regarding the role of parietal cortex in visual spatial, non-spatial and cognitive functions. We will then ask the speakers whether the framework they have developed to understand parietal involvement in a particular task setting can help understand its role in other task contexts and whether there are fundamental features of parietal cortex that enable it to participate in a diverse set of tasks and functions. There will be a total of six speakers. Sabine Kastner will address spatial mapping, attention priority signals and object representations in human parietal cortex. Yaoda Xu will describe human parietal cortex's involvement in visual short-term memory and object representation and their correspondence with behavior. Jacqueline Gottlieb will describe attention and decision related signals in monkey parietal cortex. David Freedman will examine monkey parietal cortex's involvement in visual categorization, category learning, and working memory and its interaction with other cortical areas. Peter Janssen will detail the functional organization of the monkey intraparietal sulcus in relation to grasping and 3D object representation. Melvyn Goodale will discuss the role of the parietal cortex in the control of action.

Comparative studies of posterior parietal cortex in human and non-human primates

Speaker: Sabine Kastner; Department of Psychology and The Princeton Neuroscience Institute, Princeton University

The primate parietal cortex serves many functions, ranging from integrating sensory signals and deriving motor plans to playing a critical role in cognitive functions related to object categorization, attentional selection, working memory or decision making. This brain region undergoes significant changes during evolution and can therefore serve as a model for a better understanding of the evolution of cognition. I will present comparative studies obtained in human and non-human primates using basically identical methods and tasks related to topographic and functional organization, neural representation of object information and attention-related signals. Topographic and functional mapping studies identified not only the parietal regions that primate species have in common, but also revealed several human-specific areas along the intraparietal sulcus. FMRI studies on parietal object representations show that in humans, they resemble those typically found in ventral visual cortex and appear to be more complex than those observed in non-human primates suggesting advanced functionality possibly related to the evolving human-specific tool network. Finally, electrophysiological signatures of parietal attention signals in space-based attention tasks are similar in many respects across primate species providing evidence for preserved functionality in this particular cognitive domain. Together, our comparative studies contribute to a more profound understanding of the evolution of cognitive domains related to object perception and attention in primates.

Decoding Visual Representations in the Human Parietal Cortex

Speaker: Yaoda Xu; Psychology Department, Harvard University

Although visual processing has been mainly associated with the primate occipital/temporal cortices, the processing of sophisticated visual information in the primate parietal cortex has also been reported by a number of studies. In this talk, I will examine the range of visual stimuli that can be represented in the human parietal cortex and the nature of these representations in terms of their distractor resistance, task dependency and behavioral relevance. I will then directly compare object representation similarity between occipital/temporal and parietal cortices. Together, these results argue against a "content-poor" view of parietal cortex's role in attention. Instead, they suggest that parietal cortex is "content-rich" and capable of directly participating in goal-driven visual information representation in the brain. This view has the potential to help us understand the role of parietal cortex in other tasks such as decision-making and action, both of which demand the online processing of visual information. Perhaps one way to understand the function of parietal cortex is to view it as a global workspace where sensory information is retained, integrated, and evaluated to guide the execution of appropriate actions.

Multi-dimensional parietal signals for coordinating attention and decision making

Speaker: Jacqueline Gottlieb; Department of Neuroscience, Kavli Institute for Brain Science, Columbia University

In humans and non-human primates, the parietal lobe plays a key role in spatial attention – the ability to extract information from regions of space. This role is thought to be mediated by "priority" maps that highlight attention-worthy locations, and provide top-down feedback for motor orienting and attention allocation. Traditionally, priority signals have been characterized as being purely spatial – i.e., encoding the desired locus of gaze or attention regardless of the context in which the brain generates that selection. Here I argue, however, based on non-spatial modulations found in the monkey lateral intraparietal area, that non-spatial responses are critical for allowing the brain to coordinate attention with action – i.e., to estimate the significance and relative utility of competing sensory cues in the immediate task context. The results prompt an integrative view whereby attention is not a disembodied entity that acts on sensory or motor representations, but an organically emerging process that depends on dynamic interactions within sensorimotor loops.

Categorical Decision Making and Category Learning in Parietal and Prefrontal Cortices

Speaker: David Freedman; Department of Neurobiology and Grossman Institute for Neuroscience, Quantitative Biology, and Human Behavior, The University of Chicago

We have a remarkable ability to recognize the behavioral significance, or category membership of incoming sensory stimuli. In the visual system, much is known about how simple visual features (such as color, orientation and direction of motion) are processed in early stages of the visual system. However, much less is known about how the brain learns and recognizes categorical information that gives meaning to incoming stimuli. This talk will discuss neurophysiological and behavioral experiments aimed at understanding the mechanisms underlying visual categorization and decision making, with a focus on the impact of category learning on underlying neuronal representations in the posterior parietal cortex (PPC) and prefrontal cortex (PFC). We recorded from PPC both before and after training on a visual categorization task. This revealed that categorization training influenced both visual and cognitive encoding in PPC, with a marked enhancement of memory-related delay-period encoding during the categorization task which was not observed during a motion discrimination task prior to categorization training. In contrast, the PFC exhibited strong delay-period encoding during both discrimination and categorization tasks. This reveals a dissociation between PFC's and PPC's roles in decision making and short term memory, with generalized engagement of PFC across a wider range of tasks, in contrast with more task-specific and training dependent mnemonic encoding in PPC.

The functional organization of the intraparietal sulcus in the macaque monkey

Speaker: Peter Janssen; Laboratory for Neuro- and Psychophysiology, Department of Neurosciences, KU Leuven

The lateral bank of the anterior intraparietal sulcus (IPS) is critical for object grasping. Functional magnetic resonance imaging (fMRI) (Durand et al., 2007) and single-cell recording studies (Srivastava, Orban, De Maziere, & Janssen, 2009) in macaque monkeys have demonstrated that neurons in the anterior intraparietal area (AIP) are selective for disparity-defined three-dimensional (3D) object shape. Importantly, the use of the same stimuli and tasks in macaque monkeys and humans has enabled us to infer possible homologies between the two species. I will review more recent studies combining fMRI, single-cell recordings, electrical microstimulation and reversible inactivation that have shed light on the functional organization of the IPS. Using an integrated approach (Premereur, Van Dromme, Romero, Vanduffel, & Janssen, 2015), we could identify differences in the effective connectivity between nearby patches of neurons with very similar response properties, resolving a long-standing controversy between anatomical and physiological studies with respect to the spatial extent of neighboring areas AIP and LIP. In addition, the effective connectivity of the different IPS sectors has clarified the functional organization of the anterior IPS. Finally, reversible inactivation during fMRI can demonstrate how visual information flows within the widespread functional network involved in 3D object processing. These results are not only critical to understand the role of the macaque parietal cortex, but will also contribute to a better understanding of the parietal cortex in humans.

The role of the posterior parietal cortex in the control of action

Speaker: Melvyn Goodale; The Brain and Mind Institute, The University of Western Ontario

A long history of neuropsychological research has shown the visual control of grasping and other skilled movements depends on the integrity of visual projections to the dorsal visual stream in the posterior parietal cortex. Patients with lesions to the dorsal stream are unable to direct their hands towards or grasp visual targets in the contralesional visual field, despite being able to describe the size, orientation, and location of those targets. Other patients with lesions to the ventral stream are able to grasp objects accurately and efficiently despite being unable to report the very object features controlling their actions. More recent imaging studies of both neurological patients and healthy controls has confirmed the role of the dorsal stream in transforming visual information into the required coordinates for action. In this presentation, I will discuss research from our lab showing that visual information about the metrical properties of goal objects may reach the dorsal stream via pathways that bypass the geniculostriate pathway. I will go on to show that manual interactions with some classes of objects, such as tools, requires that visual information about those objects be processed by circuits in both the ventral and the dorsal stream. Finally, I will speculate that some of the other higher-order functions of the parietal lobe, such as its evident role in numerical processing and working memory, may have evolved from the need to plan actions to multiple goals.

Attention: Saliency, awareness, learning

Saturday, May 14, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Marc Zirnsak

21.11, *8:15 am* **Representation of visual salience within the frontal eye field following reversible inactivation of parietal cortex** Marc Zirnsak[1,2](mzirnsak@stanford.edu), Xiaomo Chen[1,2], Stephen Lomber[3], Tirin Moore[1,2]; [1]Department of Neurobiology, Stanford University, Stanford, CA, USA, [2]Howard Hughes Medical Institute, Stanford University School of Medicine, Stanford, CA, USA, [3]Brain and Mind Institute, The University of Western Ontario, London, ON, Canada

The detection of salient stimuli is a key capacity of the primate visual system. It is widely believed that frontoparietal areas contribute to the computation of salience. For example, representations of salience have been demonstrated for neurons within parietal cortex and the frontal eye field (FEF). However, clear causal links between those representations and the emergence of salience are lacking. Here we investigate the effect of reversible inactivation of parietal cortex on the processing of salience by FEF neurons. We implanted two cryoloops within the intraparietal sulcus of a macaque to silence neuronal activity within nearby structures. Simultaneously, we recorded from FEF neurons and measured the responses to single stimuli, homogenous stimulus arrays, and pop-out arrays. Confirming the effectiveness of parietal inactivation, we observed behavioral biases consistent with deficits in humans exhibiting neglect and deficits observed in prior inactivation studies in monkeys. Specifically, eye movements were biased away from the contralateral hemifield. We observed this bias during a free-viewing task as well as during a two-target, free-choice task in which the monkey selects one of two targets presented in opposite hemifields with varying onset asynchronies. For the free-viewing task we observed a shift of the median number of fixations by 5 dva into the ipsilateral hemifield. In the free-choice task, inactivation biased choices away from the affected hemifield such that equal target choice probability was reached only when the contralateral target appeared 79 ms before the ipsilateral target. In addition, our recordings revealed a reduction in the selectivity to pop-out stimuli presented inside the receptive field of FEF neurons (-33% compared to pop-out stimuli presented outside the receptive field and -44% compared to homogenous stimulus arrays). In contrast, neuronal responses to single stimuli remained unchanged. These results suggest a dependence of visual salience signals within the FEF on parietal cortex.

Acknowledgement: This work was supported by National Institutes of Health grant EY014924.

21.12, *8:30 am* **Frontal eye field sources of attentional suppression during visual search** Joshua Cosman[1,2,3](joshua.d.cosman@vanderbilt.edu), Jeffrey Schall[1,2,3], Geoffrey Woodman[1,2,3]; [1]Vanderbilt University Department of Psychology, [2]Vanderbilt Vision Research Center, [3]Center for Integrative and Cognitive Neuroscience

A long debate centers on the extent to which salient, task irrelevant information captures spatial attention during visual search. This is in part because the majority of previous studies have used indirect behavioral measures as an assay of attentional capture, leading to several conflicting results and alternative interpretations. To overcome these limitations, we recorded single unit activity in frontal eye field (FEF), which provides a direct, moment-to-moment index of spatial attention, while simultaneously recording event-related potentials (ERPs) in response to salient distractor items. Critically, we found no evidence that neural correlates of spatial attention were directed to the salient distractor in either single units or ERPs. Instead, we observed a robust suppression of distractor-related activity in both measures. This suppression occurred early during visual processing in FEF units (~90ms), followed ~40ms later by suppression-related ERP responses at electrode sites over extrastriate visual cortex. This pattern of FEF suppression preceding suppression-related ERPs at posterior electrode sites is consistent with proposals that signals from FEF gate sensory processing in extrastriate cortex, and suggests that this gating occurs not only through target enhancement but also distractor suppression.

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21.13, *8:45 am* **Peripheral Distracting Information That Does Not Reach Consciousness Can Capture Attention and Prime Categorization** Colin Flowers[1](cflowers@email.arizona.edu), Mary Peterson[1,2]; [1]University of Arizona, Psychology Department, [2]University of Arizona, Cognitive Science Program

Peripheral semantic distractors capture spatiotemporal attention. We investigate whether spatiotemporal attentional capture occurs for peripheral distracting information that does not reach consciousness because it loses the competition for figural assignment. Subjects categorized a centrally-presented word as "natural" or "artificial." 110 ms before the word, two novel silhouettes were presented (80 ms) above and below fixation. Silhouettes were biased so that the inside was perceived as the figure and the outside was perceived as a shapeless ground. In Experiment 1, on experimental trials, portions of familiar objects were suggested (but not consciously perceived) on the groundside of one of the silhouettes (half natural, half artificial; crossed with target word category); nothing familiar was suggested on the groundside of the other silhouette. On control trials, nothing familiar was suggested on the groundside of either silhouette. On Experiment 2 experimental trials both silhouettes suggested the same familiar object on the groundside. Semantic priming from the category of the groundside object should affect word categorization, decreasing RTs when the category of the word and the ground object are the same relative to both control trials and different-category trials (Cacciamani, et al. 2014). Semantic priming was observed in both experiments: word categorization RTs were faster on experimental same-category than different-category trials ($ps < 0.01$). Unlike previous results obtained with these silhouettes, different-category RTs were longer than control RTs ($ps < 0.01$), whereas same-category RTs and control RTs did not differ statistically. We propose that for same-category trials, slowing due to capture summed with speeding due to semantic facilitation, thereby erasing the typical facilitatory effect. For different-category trials the slowing may be due to capture alone or to capture summed with interference. These data are the first to show that peripheral distracting information that does not reach consciousness can capture attention and prime categorization responses.

Acknowledgement: ONR N00014-14-1-0671

21.14, *9:00 am* **Context-given benefits: Saliency-based selection as a function of autism and psychosis traits** Ahmad Abu-Akel[1](ama289@bham.ac.uk), Ian Apperly[1], Mayra Spaniol[1], Joy Geng[2,3], Carmel Mevorach[1]; [1]School of Psychology, University of Birmingham, UK, [2]Department of Psychology, University of California Davis, Davis, CA, USA, [3]Center for Mind and Brain, University of California Davis, Davis, CA, USA

ntroduction: Independent lines of evidence suggest a potentially contrasting effect of autism and schizophrenia and the broader spectrum of their traits in neurotypical participants on attention processes, particularly in conditions requiring distractor suppression. However, previous studies fail to highlight a consistent effect on performance. One possible explanation is the type of attention suppression that is called upon (rather than the need to suppress distractors per se). The present study examined (1) whether autism versus psychosis expressions induce contrasting effects on target selection in the presence of a non-target salient element, and (2) whether this effect varies in tasks that tap reactive (post stimulus presentation) versus proactive (pre stimulus presentation) attentional control. Method: Autism tendencies and psychosis proneness were assessed in tandem in a total of 127 neurotypical adults. In study 1, 58 participants performed an adapted version of the morphed face-discrimination task that taps proactive attentional control. In study 2, 69 participants performed a visual search task that taps reactive control. Results: Both studies show that autism and psychotic traits exert a contrastive effect on the processing of a target in the presence of non-target salient element. In the proactive task, high autistic traits were beneficial but high psychosis proneness was detrimental for performance. Strikingly, this pattern reversed for the reactive task, where high psychosis proneness was beneficial and high autistic traits were detrimental for performance. Conclusion: The results provide converging evidence for the contrastive effect of autism and psychosis traits on target selection and distractor suppression within the same cohort. Critically, the pattern suggests a double dissociation between the two with autism and psychosis traits associated with proactive and reactive modes of selection and suppression, respectively. These results can have important implications for clinical interventions as they identify context-given benefits for autism and psychosis.

21.15, *9:15 am* **Attention and consciousness exhibit different gain functions in afterimage experiments** Jeroen van Boxtel[1,2](j.j.a.vanboxtel@gmail.com); [1]School of Psychological Sciences and Monash Institute of Cognitive and Clinical Neurosciences, Monash University, Clayton 3800 Vic, Australia, [2]Division of Biology, California Institute of Technology, Pasadena, CA 91125

The link between attention and consciousness is fiercely debated, and it is not yet known whether they operate through similar, or widely different mechanisms. The influences of attention and consciousness on sensory processing can be described as modulations of a baseline response function, and are called gain modulations or gain functions. We derived behavioural contrast response curves, by measuring afterimage durations for a range of inducer stimulus contrasts. Attention was manipulated by asking the participants to perform a distracting rapid serial visual presentation task. Conscious perception was manipulated by showing (or not showing) an interocular mask. We found that, overall, afterimage durations increase with increasing contrast. We further show that attention decreases afterimage durations, and operates through a response-gain function. Conversely, consciousness increases afterimage durations, and operates through a contrast-gain function. To obtain a better mechanistic insight, we fitted various versions of a hierarchical normalization model to the data, and compared the fit quality of these models using the Bayesian Information Criterion. This analysis showed that the best model required 2 levels, with the consciousness manipulation modulating the first level, and attention modulating the second level. These results demonstrate that attention and consciousness exhibit different types of gain control, and enter the normalization process at different processing levels. Our results disprove the intuitive idea that attention and consciousness are always tightly entwined, and advocate for careful control of parameters that influence attention and consciousness in future research.

21.16, *9:30 am* **Learning to search for two targets with unequal occurrence rates: The role of short-term versus long-term learning** Sha Li[1](lixx3632@umn.edu), Yuhong V. Jiang[1,2]; [1]Department of Psychology, University of Minnesota, [2]Center for Cognitive Science, University of Minnesota

Selective attention is strongly influenced by the location or feature probability of a search target. Previous visual search studies showed that both long-term statistical learning and short-term inter-trial priming contributed to attentional learning of a target's location probability. Yet the relative contribution of long-term and short-term mechanisms in attention learning of a target's feature probability remains unclear. Here we investigated how people searched for two potential targets that appeared with unequal occurrence rates. We examined time course, persistence and primacy effects of feature probability learning. Participants searched for two pre-specified target colors, one of which appeared on each trial, and reported the target's orientation. The two targets appeared with unequal probability, requiring participants to learn to adjust their search priority. In three experiments, we showed that participants rapidly acquired an attentional preference for the more probable target. Unlike location probability learning and other forms of visual statistical learning, target probability learning quickly extinguished when the two targets became equally probable. In addition, when the two targets' probability reversed in the experiment, participants also rapidly adjusted to the new probability structure. Learning and the adjustment of learning were unrelated to explicit awareness about the targets' probability. These results indicate that, unlike location probability learning, target probability learning reflects short-term learning. Long-term learning was absent or trivial relative to the influence of short-term search history. Short-term repetition priming provided a reasonable account for the rapid acquisition and rapid extinction of the feature probability effect. We propose that people optimize the search template by considering very recent search history.

Perception and Action: Reaching and grasping

Saturday, May 14, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Katja Fiehler

21.21, *8:15 am* **Differential cortical responses to salience during perception and goal-directed action** J. Daniel McCarthy[1](dan_mccarthy@brown.edu), Christine Gamble[1], Joo-Hyun Song[1,2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, Providence RI, [2]Brown Institute for Brain Science, Brown University, Providence RI

In daily life, we are commonly faced with multiple objects that compete for selection. For example, crossing the street requires shifting attention between traffic signals, oncoming cars, other pedestrians, etc. While selection can be driven by behavioral goals, physically salient stimuli, such as flashing lights or bright road signs, often capture attention as well. Perceptual research demonstrates that highly salient distractors strongly capture attention and are more detrimental to behavior than less salient distractors. Contrary to this claim, however, our lab recently demonstrated that while this is the case for perception, the opposite pattern is observed for action: highly salient singleton distractors interfered less with target selection than weak ones (Moher, Anderson & Song, 2015). The authors concluded that distinct salience-driven suppression mechanisms exist for perception and goal-directed action. Here, we use fMRI to identify brain regions involved in this disparity. Our results demonstrate that clusters bordering the Anterior Cingulate Cortex (ACC) and medial frontal gyrus (MFG)—areas both previously implicated in conflict monitoring and task goal maintenance—were more active for less salient distractors during a perception task. Importantly, however, this pattern was reversed when participants performed goal-directed reaches toward the target: highly salient distractors led to increased ACC and MFG activation compared to less salient distractors. Research indicates that increased activity within these regions is associated with resolving conflict throughout goal-directed tasks. Accordingly, we offer the hypothesis that when goal-directed action is not required, less salient distractors are suppressed more effectively as indicated by faster reaction times and a higher BOLD signal. In contrast, highly salient distractors trigger suppression during goal-directed action, resulting in more efficient target selection and increased AAC/MFG activation. These results suggest that the same or similar cortical regions underlie dissociable effects of salience depending on action requirements.

Acknowledgement: SPRF-NSF 1514246, NIGMS-NIH IDeA P20GM103645

21.22, *8:30 am* **One-shot correction of sensory prediction errors produces illusion-resistant grasping without multiple object representations** Evan Cesanek[1](evan_cesanek@brown.edu), Carlo Campagnoli[2], Fulvio Domini[3]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, [2]Center for Neuroscience and Cognitive Systems@UniTn, Italian Institute of Technology

Major theories of human visual processing postulate the existence of independent visual systems for action and perception, notably rejecting the more parsimonious assumption that common visual encodings underlie both functions. To investigate the dual-streams hypothesis, previous studies have tested whether grasping movements directed at objects in visual illusions are affected to the same extent as perceptual reports of object size. In many studies, grasp control has been found to resist illusions, apparently supporting the idea that vision for action separately computes accurate size representations. However, an alternative explanation is that repetitive grasping of a small set of target objects (which is ubiquitous in such studies) induces sensorimotor adaptation that washes out the illusion effect on grasping despite the distorted visual encoding. In support of this novel account, we show that repeated grasping of objects in a size-distorting illusion produced increasingly accurate grip pre-shaping across 20 trials while the illusion's effect on conscious perception persisted. Examining this learning process on a trial-by-trial basis, we found that grasping errors induced by a switch in the illusory context were immediately corrected when the next grasp was directed at the same object. Critically, this one-shot learning shows that the gradual reduction of the illusion effect over multiple trials does not involve iterative updating of a separate object-size representation, but rather that it may emerge from a memoryless error correction process. In line with this proposal, conscious perceptual estimates of object size obtained prior to each grasp were

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found to be the best predictor of the maximum grip aperture (MGA), indicating common visual encoding of object size for perception and action. Our findings demonstrate that when feedforward visual signals convey inaccurate size information, visuomotor networks will integrate visual and haptic prediction errors to achieve appropriate movement calibration.

21.23, *8:45 am* **Allocentric coding of reach targets in naturalistic visual scenes** Katja Fiehler[1](katja.fiehler@psychol.uni-giessen.de), Mathias Klinghammer[1], Immo Schütz[2], Gunnar Blohm[3]; [1]Experimental Psychology, Justus-Liebig-University Giessen, Germany, [2]Physics of Cognition, Chemnitz University of Technology, Germany, [3]Centre for Neuroscience Studies, Queen's University, Kingston, Ontario, Canada

Goal-directed reaching movements rely on both egocentric and allocentric target representations. So far, it is widely unclear which factors determine the use of objects as allocentric cues for reaching. In a series of experiments we asked participants to encode object arrangements in a naturalistic visual scene presented either on a computer screen or in a virtual 3D environment. After a brief delay, a test scene reappeared with one object missing (= reach target) and other objects systematically shifted horizontally or in depth. After the test scene vanished, participants had to reach towards the remembered location of the missing target on a grey screen. On the basis of reaching errors, we quantified to which extend object shifts and thus, allocentric cues, influenced reaching behavior. We found that reaching errors systematically varied with horizontal object displacements, but only when the shifted objects were task-relevant, i.e. the shifted objects served as potential reach targets. This effect increased with the number of objects shifted in the scene and was more pronounced when the object shifts were spatially coherent. The results were similar for 2D and virtual 3D scenes. However, object shifts in depth led to a weaker and more variable influence on reaching and depended on the spatial distance of the reach target to the observer. Our results demonstrate that task relevance and image coherence are important, interacting factors which determine the integration of allocentric information for goal-directed reaching movements in naturalistic visual scenes.

Acknowledgement: German Research Foundation IRTG 1901, Fi1567/3-2

21.24, *9:00 am* **3 Dimensional Binocular Eye and Hand Coordination in Normal Vision and with Simulated Visual Impairments** Guido Maiello[1,2](guido.maiello.13@ucl.ac.uk), MiYoung Kwon[3], Peter Bex[2]; [1]UCL Institute of Ophthalmology, University College London, London, UK, [2]Department of Psychology, Northeastern University, Boston, MA, USA, [3]Department of Ophthalmology, University of Alabama at Birmingham, Birmingham, AL, USA

It is well known that the motor systems controlling the eyes and the hands are closely linked when executing tasks in peripersonal space. We examine how this coordination is affected by binocular and asymmetric monocular simulated visual impairment. In a stereoscopic display, human observers were required to closely track with their gaze a 1 degree Gabor patch moving in three dimensions on a 1/f noise background. The movement of the Gabor patch was either directly controlled by the observer's unseen hand in real time; or followed their hand movements executed in a previous trial. Hand position was recorded with a Leap Motion hand tracker, and gaze position was recorded with an Eyelink 1000 eye tracker. We simulated visual impairments by Gaussian blurring the visual stimuli independently in each eye. Tracking accuracy was defined as the average correlation coefficient between gaze position and target position along the fronto-parallel plane (pursuit) or the sagittal plane (vergence). We observed a critical blur level up to which pursuit and vergence eye movements maintained fronto-parallel and sagittal tracking accuracy independent of blur level. Monocular blur affected fronto-parallel tracking less than binocular blur, however small amounts of monocular blur impaired tracking in depth much more than binocular blur. Target tracking was more accurate when observers were directly controlling the stimulus than when they tracked a previous hand movement and this benefit was more pronounced with degraded visual input. This suggests that under conditions of visual uncertainty, proprioceptive information is weighed more heavily. Our results confirm that the motor control signals that guide hand movements are utilized by the visual system to plan eye movements. Our findings suggest that hand-eye coordination might be monitored to better understand functional impairments associated with eye disease and may be employed to rehabilitate an array of monocular and binocular visual impairments.

Acknowledgement: NIH grant R01EY021553

21.25, *9:15 am* **Neural coding of action planning: visual processing or visual memory?** Simona Monaco[1](simona.monaco@gmail.com), Elisa Pellencin[2], Malfatti Giulia[1], Turella Luca[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy, [2]Dipartimento di Scienze della Cognizione e della Formazione, University of Trento, Italy

Recent neuroimaging evidence has shown that action preparation shapes activity in areas of the ventral stream known to be involved in visual recognition of objects. Here we investigated whether this modulation is related to the visual processing or visual memory of the object properties that are relevant for the upcoming action. To answer this question, we used a slow event-related fMRI paradigm that independently manipulated vision of the object (Vision or No Vision) and action type (Grasp or Move hand). Movements consisted of either grasping the object or moving the open hand beside the object without touching it. Critically, processing of object properties was crucial for the Grasp but not Move hand condition as an interaction with the object was required for grasping but not open hand movements. Sixteen right-handed participants performed delayed movements with and without visual feedback using their dominant hand. At the beginning of each trial an auditory cue instructed participants whether or not to close their eyes and the action to be performed at the end of the trial. A delay of 10 seconds was followed by the go cue. Using a multivariate pattern analysis of fMRI data, we found that the Lateral Occipital (LO) area showed above chance decoding accuracy for planning Grasp vs. Move hand actions in the Vision condition while the tactile-visual subdivision of LOC (LOtv) showed above chance decoding accuracy for planning Grasp vs. Move hand actions in the Vision as well as in No Vision condition. These results suggest that object processing in LO and LOtv is shaped by whether or not an interaction with the object is planned. In addition, while activity in LO is shaped by online visual processing of the object, activity in LOtv is shaped by visual processing as well as by visual memory of the object.

Acknowledgement: Futuro in Ricerca 2013 (FIRB 2013) to Luca Turella, project RBFR132BKP

21.26, *9:30 am* **Hierarchical Organization of Action Encoding Within The Human Brain** Luca Turella[1](luca.turella@gmail.com), Raffaella Rumiati[2], Angelika Lingnau[1,3,4]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, [2]Scuola Internazionale Superiore di Studi Avanzati (SISSA), [3]Department of Psychology and Cognitive Science, University of Trento, [4]Department of Psychology, Royal Holloway University of London

Our interactions with the environment require the smooth execution of object-directed actions. These actions seem to be represented not only in terms of specific muscular patterns, but also in terms of the achievement of a more general goal, e.g. grasping an object irrespective of the means (e.g. the adopted effector). Neuroimaging studies support the idea that actions might be represented at different levels of abstraction, i.e. generalizing across different motor features. Recent studies using MVPA of fMRI data showed action representations tied to the hand performing the action (i.e. at an effector-dependent level), but also generalizing across left and right hand (i.e. at an effector-independent level). Here we used MVPA of fMRI data to examine action representations that generalize across effector, hand orientation, or both. Participants were instructed to perform different non-visually guided object-directed actions. The experimental conditions were embedded in a 2x2x2 factorial design with the following factors: action type (precision grip, whole hand grip), hand orientation (0°, 90°) and effector (left hand, right hand). To investigate the encoding of action representations at different levels of abstraction, we used a whole-brain cross-condition MVPA searchlight approach. Specifically, we classified the type of action within and across hand orientation and effector. Our results showed widespread encoding of specific effector-dependent actions (within effector and hand orientation) in the fronto-parietal prehension network. Several regions also showed encoding for more abstract effector-specific actions, generalizing across hand orientation. Finally, a more circumscribed set of cortical areas, comprising posterior parietal, premotor and lateral occipitotemporal regions, hosted effector-independent and orientation-independent action representations. These data widen our understanding on how actions are represented in the brain by demonstrating that, even during movement execution, actions are encoded following a hierarchical organization spanning different levels of abstraction.

Acknowledgement: FIRB 2013 Grant (project RBFR132BKP)

Perceptual Learning: Mechanisms and applications

Saturday, May 14, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Cong Yu

22.11, *10:45 am* **Reward reactivates and facilitates visual perceptual learning during REM sleep** Aaron Berard[1](aaron_berard@brown.edu), Masako Tamaki[1], Tyler Barnes-Diana[1], Jose Nañez[2], Takeo Watanabe[1], Yuka Sasaki[1]; [1]Laboratory for Cognitive and Perceptual Learning, Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, [2]Department of Social and Behavioral Sciences, Arizona State University

Visual perceptual learning (VPL) is defined as a long-term performance improvement on a perceptual task as a result of perceptual experience. It has been found that sleep strengthens and consolidates VPL. In parallel to the effect of sleep, reinforcement given through external primary reward (such as water) has been found to facilitate VPL. However, it remains unclear whether sleep and reward independently influence VPL or whether they interact with each other. Our previous research has found a significant interaction between reward and sleep in performance improvement on a visual task, suggesting that the effect of reward on VPL is enhanced during sleep. Here, we investigated the neural mechanism of the interaction of reward and sleep on VPL of the texture discrimination task (TDT). Twenty-two participants were trained and tested on TDT before and after a nap during which brain activity was monitored with polysomnography. During training, half of the participants received auditory feedback and water as a reward through a tube for a correct response (reward group), while the other half only received auditory feedback for a correct response (no-reward group). First, we replicated the previous results that performance improvement after a nap was significantly larger for the reward group than for the no-reward group. Second, the reward group showed significantly longer REM sleep periods than the no-reward group. Third, during REM sleep, the reward group showed both significantly higher alpha activity at the fronto-central regions that are involved in the brain's reward system and significantly lower theta activity at the untrained side of the visual cortex, in comparison to the no-reward group. Finally, these neural modulations by reward were highly correlated with performance improvements. These results suggest that reward given during training allows the reward system to reactivate and interacts with visual processing during subsequent REM sleep.

Acknowledgement: NIH R01EY019466, R01MH091801, NSF BCS 1539717

22.12, *11:00 am* **Response mode specificity of perceptual learning** Lukasz Grzeczkowski[1](lukasz.grzeczkowski@epfl.ch), Fred Mast[2], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechique Fédérale de Lausanne (EPFL), [2]Department of Psychology, University of Bern

Perceptual learning is usually stimulus specific and, therefore, assumed to occur within the sensory areas or when mapping sensory evidence onto decisions. The motor responses, involving all perceptual learning experiments, are thought to play no role in the learning process. Here, we show that this is not true. Perceptual learning is specific for the stimuli, the task and even the type of motor response. In the first experiment, observers trained with a standard three-line bisection task and indicated the offset direction of the central line by pushing either the left or the right button. Before and after training, observers adjusted the central line of the same bisection stimulus using a computer mouse. They were asked to adjust the line to the smallest visible offset. As expected, performance improved through training. Surprisingly, learning did not transfer to the untrained mouse adjustment condition, even though the visual stimulus was almost the same as during training. The second experiment was the same as experiment 1 except that response types were reversed, i.e., the training was performed with the mouse adjustment task and pre- and post-tests with button presses. As in the first experiment, performance improved trough training and learning did not transfer to the untrained button presses condition. In the third experiment, we repeated the second experiment and recorded the 5600 mouse adjustment traces of each observer during training. The traces were played back to new observers, i.e., observers saw how other participants adjusted the central line. Observers indicated the offset direction of the last position of the central line by button press. Training led to significant learning. There was no transfer to the untrained button presses or mouse adjustments as determined in pre- and post-tests. Our results support theories where stimuli are coded together with the corresponding actions.

22.13, *11:15 am* **Statistical learning creates novel object associations via transitive relations** Yu Luo[1](yuluo@psych.ubc.ca), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

The visual system can readily extract statistical relationships between objects over space and time. What is more remarkable is the ability to form new associations between objects that have never co-occurred before. What cognitive mechanisms support the formation of these new associations? Here we propose that statistical learning not only produces knowledge about objects that have previously co-occurred, but also generates new connections between objects that have never directly appeared together. Observers viewed a continuous sequence of colors while performing a cover task. Unbeknownst to the observers, the colors were grouped into base pairs (e.g., A-B, B-C). We found that observers learned not only the base pairs, but also a novel pair of objects (A-C) that had never co-occurred before and could only be associated through transitive relations between the base pairs (Experiment 1). We extended the chain of associations by adding one more base pair (e.g., A-B, B-C, C-D), but this time the observers did not learn the novel pair (A-D), despite having successfully learned all the base pairs (Experiment 2). This reveals the limit in the transitive associations afforded by statistical learning. We also explored how transitive associations are formed across the categorical hierarchy. In Experiment 3, after viewing a sequence of city pairs (e.g., New York-London), observers automatically learned subordinate park pairs (Central Park-Hyde Park), and also superordinate country pairs (USA-UK). Importantly, none of the park pairs or country pairs had been presented previously, and could only be associated through the city pairs. However in Experiment 4, after viewing a sequence of park pairs, observers only showed successful learning of city pairs but not country pairs, reflecting the limit in the transitive associations across the categorical hierarchy. In sum, the findings suggest that statistical regularities provide a scaffold through which new associations between objects are automatically formed.

Acknowledgement: NSERC Discovery Grant

22.14, *11:30 am* **The role of rule-based learning in featural generalization of visual perceptual learning (VPL) revealed in the effects of category learning on VPL** Qingleng Tan[1](qingleng_tan@brown.edu), Takeo Watanabe[1]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown Univeristy

Visual perceptual learning (VPL) is defined as long-term improvement in visual performance as a result of visual experience. In many cases, VPL is largely confined to a feature that was presented during training, which refers to feature specificity of VPL. However, recent research has indicated that feature specificity can be abolished by a training-plus-exposure procedure. This finding led some researchers to suggest that VPL is governed by rule-based learning. However, the role of rule-based learning in VPL has not been empirically clearly examined. Since category learning is known to be a type of rule-based learning, the present study investigated whether and how category learning governs VPL by examining the effect of category learning on VPL. We trained 6 human subjects to classify gabor orientations within a 180° range into two categories. After one session of training of category learning (500 trials), participants underwent 5 days' training on a detection of one gabor orientation presented at the fovea. Before and after training on the orientation, participants were tested for the detectability of an orientation from the same category (SC) as the trained orientation, another orientation from a different category (DC), and also the trained orientation. The distance between the trained and SC orientations was the same as the distance between the trained and DC orientations. The results showed that detection performances on the SC orientation and the trained orientation were significantly greater after than before training, but not on the DC orientation. These results indicate that category learning makes VPL of a feature transferable to features within the same category as the trained feature. Based on the results, we concluded that rule-based learning can drive VPL. The intraparietal sulcus (IPS) has been implicated in rule-based learning and category learning. Thus, the IPS may play a role in generalization VPL.

Acknowledgement: NIH R01EY019466 Systematic Psychophysical Investigation of Visual Learning

22.15, *11:45 am* **What is learnt when learning to point at 'invisible' visual targets?** Derek Arnold[1](d.arnold@psy.uq.edu.au), Vivien Yuen[1]; [1]Perception Lab, The University of Queensland

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Binocular masking is a particularly interesting means of suppressing human visual awareness, as the images it renders subjectively 'invisible' nonetheless excite robust activity in human cortex. Recently, binocular masking has been leveraged to show people can be trained to better interact with inputs that remain, subjectively, invisible. Here we ask what is learnt in such circumstances. Do people gain better insight into their' true level of sensitivity, allowing motor planning to be better guided by an unchanged sensory code? Or is signal encoding modulated by training, resulting in a heightened level of objective sensitivity? Our data suggest the latter. We had people train for five consecutive days, to poke targets presented in one of three masked locations. Target intensity was set to a fraction of the participants' pre-training objective detection threshold. During training, people categorised targets as visible or invisible (providing a confidence rating concerning task performance in the latter circumstance). Feedback was provided when the participant had reported not having seen the target, and statistical analyses were restricted to data from these trials. We found that people became better at selecting the target location with training, even when they insisted they could not see it. More important, post-training we found objective thresholds for target detection had improved. We regard our data as evidence that the strength of binocular masking is malleable – reduced by training to localise masked targets, resulting in an enhanced objective sensitivity to masked target location.

Acknowledgement: The Australian Research Council

22.16, *12:00 pm* **Dichoptic perceptual training in juvenile amblyopes with or without patching history** JunYun Zhang[1](zhangjunyun@pku.edu.cn), XiangYun Liu[2], Cong Yu[1]; [1]Department of Psychology and Peking-Tsinghua Center for Life Sciences, Peking University, [2]Department of Ophthalmology, Tengzhou Central People's Hospital, Tengzhou, Shandong Province, China

Dichoptic training is becoming a popular tool in amblyopia treatment. Here we investigated the effects of dichoptic training on juvenile amblyopia no longer responsive to patching treatment (PT group) or never patch treated (NPT group). Training consisted of three stages. (1) 10 PT and 10 NPT amblyopes (8-17 years, 15-anisometropic, 3-ametropic, 1-strabismus, 1-mixed) received dichoptic de-masking training for 40 hours. They used AEs to practice contrast discrimination of Gabors that were dichoptically masked by a band-filtered noise pattern simultaneously presented in NAEs. Dichoptic learning is indexed by the increase of maximal tolerable noise contrast (TNC) for AE contrast discrimination. Training improved maximal TNC by 350% in PT and 480% in NPT, which translated to stereoacuity improvements by 4.6-lines in PT and 3.0-lines in NPT, and AE visual acuity improvements by 1.3-lines in PT and 2.1-lines in NPT. (2) The amblyopes further received stereopsis training for another 40 hours. Training improved stereoacuity by 2.4-lines in PT and 0.5-lines in NPT, and AE acuity by 0 line in PT and 0.5 lines in NPT. Seven PT amblyopes regained normal stereoacuity (20~50 arcsec) after two stages of training. (3) Extra monocular AE grating acuity training (30 hours) failed to improve grating acuity in both groups. Neither did it produce further AE acuity and stereoacuity gains. After training the visual acuity and stereoacuity gains persisted for at least one year. Dichoptic training improved vision in both PT and NPT juvenile amblyopes. The PT group with milder amblyopia benefited substantially more in stereoacuity (6.0-lines), probably because improved AE acuity (1.3-lines) could translate to greater balance of binocular vision and thus better stereoacuity. The NPT group benefited more in visual acuity (2.6-lines), consistent with our previous report (Liu et al., 2011). Our study confirmed the effectiveness of dichoptic training approaches in the treatment of juvenile amblyopia.

Acknowledgement: Natural Science Foundation of China grants 31230030 (CY) and 31470975 (JYZ)

22.17, *12:15 pm* **Visual discrimination training shrinks cortically blind fields and improves quality of life in chronic stroke patients** Matthew Cavanaugh[1,2](matthew_cavanaugh@urmc.rochester.edu), Selena Lilley[1], MIchael Melnick[1,3], Adin Reisner[1], Krystel Huxlin[1]; [1]Flaum Eye Institute, University of Rochester, [2]Neuroscience Graduate Program, University of Rochester, [3]Brain and Cognitive Sciences, University of Rochester

We previously showed training to recover multiple visual discrimination abilities at trained locations in cortically blind (CB) fields (Huxlin, et al., 2009, Das et al., 2014). Here, we asked whether such training also decreases the size of the visual deficit, and whether this is impacted by number of training sessions, locations trained, time since stroke and patient age. Humphrey Visual Fields (HVF) were collected in 19 CB subjects – 5 untrained controls and 14 subjects trained on static orientation and/or global direction discrimination tasks (see Huxlin et al., 2009; Das et al., 2014). After recovering normal performance at a minimum of one blind field location, or after an interval of 1-13 months in the controls, HVFs were re-measured. Pre- and post-training maps of luminance sensitivity were generated by convolving 24-2 and 10-2 HVFs in each eye, averaging the two eyes, and interpolating between sampled locations. Only changes > 6dB were considered significant. Without training, both increases and decreases in sensitivity were observed (over 16 ± 5 deg2 and 9 ± 5 deg2 of the HVF, respectively). Training increased luminance sensitivity over an area 84 ± 16 deg2 in size; no decreases in sensitivity were observed. Curiously, improvements were not restricted to trained locations, but extended in a band 5 ± 1° wide along the pre-training blind field border. Improvement area was significantly correlated with number of training sessions and locations trained, but not with time since stroke or patient age. Finally, quality of life was assessed pre- and post-training using the National Eye Institute's VFQ-25 questionnaire. Training caused significant improvements in near and distance activities, and in the mean vision-related score. Thus, visual discrimination training in CB fields recovered luminance sensitivity over much of the blind field border, an improvement that appeared sufficient to increase visual functioning and quality of life.

Visual Memory: Working and long-term

Saturday, May 14, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Daryl Fougnie

22.21, *10:45 am* **Visual working memory relies on separate viewpoint-specific ensemble and viewpoint-invariant object representations** Timothy Brady[1](timbrady@ucsd.edu); [1]Department of Psychology, University of California, San Diego

When participants are asked to remember objects in working memory, they encode not only information about individual items, but also information about the ensemble properties of the display. For example, when shown a display of fine-lined Chinese characters and heavy 3D cubes, participants remember not only particular items but also global texture, like which regions of the display are darker vs. lighter (e.g. Brady & Alvarez, 2015). These spatial ensemble representations boost memory performance by providing an additional source of information about a visual display above and beyond information about individual items. In the current experiments, I show that participants' spatial ensemble representations are dissociable from their representations of individual items. In particular, spatial ensemble representations are considerably more viewpoint-dependent than item representations. Across a variety of tasks, participants' ability to use ensemble information to detect changes is severely impaired after a 3D rotation of the display. In contrast, their item representations are unaffected by 3D rotations. This effect is specific to 3D, not 2D, transformations: Spatial ensemble representations are unaffected by 2D transformations like translation or scaling. For example, in one experiment, participants were shown displays of 3D cubes and Chinese characters and asked to detect either cross-category changes (cube->character; which disrupts the spatial ensemble) or within-category changes (cube > cube, which requires individual item memories). The ability to detect cross-category changes was significantly impaired by 3D rotation (Dd-prime: 0.37), whereas detection of within-category changes was completely unaffected (Dd-prime: -0.06; interaction: p=0.007). Across a variety of similar experiments, spatial ensemble representations are reliably viewpoint-specific. Thus, spatial ensemble representations may function independently of our object memory system. Spatial ensemble representations may instead be related to the brain's scene processing network, which remains viewpoint-specific further along the visual processing hierarchy than does the object system (Epstein et al. 2003).

22.22, *11:00 am* **Lapses of sustained attention cause later forgetting in visual long-term memory** Megan deBettencourt[1](debetten@princeton.edu), Kenneth Norman[1,2], Nicholas Turk-Browne[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

When performing any task for an extended period of time, attention fluctuates between good and bad states. These fluctuations affect perception and performance in the moment, but may also have consequences for what gets encoded into memory. Here we test this hypothesis by monitoring attentional fluctuations in behavior during a response-inhibition task and exploiting them to predict and manipulate subsequent memory. In the response-inhibition task, participants categorized scenes as indoor or outdoor by pressing one of two buttons. Critically, 90% of images were from one subcategory (e.g., indoor) to encourage habitual responding and increase the error rate when the images from the other subcategory (e.g., outdoor) appeared. Sustained attention was defined based on response times (RTs) to the dominant subcategory, as previous studies have shown that errors for the rare subcategory are preceded by relatively fast RTs. Thus, we operationalized a bad attentional state as a period of fast RTs and a good attentional state as a period of slow RTs, relative to the mean RT. Participants then completed a surprise recognition memory test in which they were shown old images of both subcategories from the response-inhibition task and new lure images. In Experiment 1, we found that attentional state during encoding correlated with subsequent memory, with images encoded in a bad state more likely to be forgotten. In Experiment 2, we tracked attentional states in real time and triggered the presentation of an image from the rare subcategory when participants strongly entered a state. Images triggered in a bad state were more likely to be forgotten than images triggered in a good state. These findings suggest that sustained attention has downstream consequences for what we remember. By adapting the experimental design based on participants' behavior, we were able to establish a stronger causal link between sustained attention and memory.

Acknowledgement: NIH R01 EY021755, NSF BCS 1229597, The John Templeton Foundation, Intel Labs

22.23, *11:15 am* **Asymmetric confidence intervals reveal hidden information in working memory** Daryl Fougnie[1,2](darylfougnie@gmail.com), Anish Kanabar[2], Timothy Brady[2,3], George Alvarez[2]; [1]Department of Psychology, New York University Abu Dhabi, [2]Department of Psychology, Harvard University, [3]Department of Psychology, University of California, San Diego

Studies have shown that working memory capability is limited, even for simple visual features. However, typical studies may underestimate the amount and richness of information in memory by relying on paradigms where participants only make a single recall response. To examine this possibility, we had participants memorize five briefly presented colored circles and then adjust a randomly probed item's color by selecting a color along a circular color space. Responses were noisy and many were far from the true color, suggesting poor memory. However, we found that this task significantly underestimates the information people remember about an item: even when participants responded inaccurately on an adjustment task, they performed reliably above chance when given the opportunity to make a second response (selecting which of two colors was present using a forced-choice task). Why do people seem to know more about items in memory then they convey in a single response? One possibility is that memory representations aren't well described by a single discrete color, but are rich and probabilistic. In a second experiment, we added a confidence judgement to the adjustment task. After selecting a color, participants drew arcs independently in the clockwise and counterclockwise direction to indicate their confidence in their response. Not only was reported uncertainty highly correlated with observed uncertainty (demonstrating metaknowledge), but the asymmetry in arcs predicted the direction of the correct answer (60.8 % of longer arcs were toward the correct answer). The information in the asymmetric arcs was also highly correlated ($r=.80$, $p< .05$) with participants' ability to choose the correct color on a subsequent forced-choice task, suggesting these measures reflect the same construct. We conclude that participants know significantly more than is reflected in a single response, perhaps because this knowledge is probabilistic and thus difficult to condense into a single report.

22.24, *11:30 am* **The limitations of visual working memory in prioritizing visual stimuli for conscious access** Dirk van Moorselaar[1](d.van.moorselaar@vu.nl), Jan Theeuwes[1], Christian Olivers[1]; [1]VU University Amsterdam

Models of biased competition assume that memory-related activation in early visual areas biases processing towards memory-matching items. Consistent with this, evidence from breaking continuous flash suppression (b-CFS, where a pattern to one eye is temporarily rendered invisible by presenting a dynamic pattern to the other eye) shows that stimuli matching the content of visual working memory (VWM) are prioritized for conscious experience. So far this has been shown for single items in memory, in combination with single targets presented in the display. In the present set of experiments we investigated the limitations of working memory in driving b-CFS, as well as the role of competition in the target display. When the target was the only item in the display, results showed that targets matching the current memory broke through CFS sooner than non-matching targets. Importantly, this break-through benefit was reduced by half when memory load increased from one to two, suggesting that the prioritization for conscious access becomes less efficient when more than one item has to be maintained in VWM. When the target was not the only item in the display, the break-through benefit again decreased when load increased from one to two. However, these benefits were no longer specific to CFS as the same results were obtained in the monocular control condition. This suggests that when multiple items are suppressed VWM content is no longer prioritized for conscious experience, but VWM can still benefit attentional selection of matching visual input. A subsequent experiment showed that this benefit was strategic rather than automatic. When the VWM content could only match a competing distractor, it no longer had an effect on b-CFS. Implications for models assuming a single active representation in VWM are discussed.

22.25, *11:45 am* **Neural and behavioral evidence for an online resetting process in visual working memory** Halely Balaban[1,2](halelyba@mail.tau.ac.il), Roy Luria[1,2]; [1]Sagol School of Neuroscience, Tel Aviv University, [2]The School of Psychological Sciences, Tel Aviv University

Items around us constantly change, and visual working memory (VWM) must change its representations accordingly. One way of achieving this is updating, but sometimes changes are too large to be incorporated into existing representations. We suggest that processing such changes relies on a resetting of VWM, a process in which the old representations are removed from VWM, and the items are re-encoded as novel. We presented moving shapes that separated into parts in a shape change-detection task. While the joint movement was task-irrelevant, it supported the interpretation of the parts as a single object. Hence, individuating the parts (which was needed following their separation) was very challenging prior to separation. To determine the online status of VWM, we monitored the contralateral delay activity (CDA), an electrophysiological marker whose amplitude rises as more items are held in VWM. Following the separation, the CDA amplitude sharply dropped, indicating that VWM contents were removed, followed by the re-encoding of the parts as novel objects, which was reflected in a rise in the CDA amplitude. This effect was replicated with different stimuli, to illustrate its generality. Conversely, when individuation was possible already during the joint movement, the separation was followed by an updating process without resetting (i.e., CDA amplitude steadily rose, since more VWM-units were present, without a drop). We demonstrate that resetting does not depend on separation. Rather, we show that under certain conditions, resetting, as indicated by the CDA drop, is evident when an object is replaced by a different object. Finally, we provide behavioral evidence that during the resetting process, VWM is blind to salient changes in the items' shape. Overall, this work introduces the novel process of online resetting in VWM, its neural signature and its behavioral consequences.

22.26, *12:00 pm* **Oscillatory correlates of visual working memories uploaded from long-term memory** Keisuke Fukuda[1](Keisuke.fukuda@vanderbilt.edu), Geoffrey Woodman[1]; [1]Department of Psychological Sciences, Vanderbilt University

Our visual working memory (VWM) allows us to represent a limited amount of visual information in the service of current task demands. Studies thus far have almost exclusively examined situations in which new visual inputs are maintained over brief retention intervals. However, several theories propose that visual information is also maintained in VWM when it is retrieved from visual long-term memory (VLTM). 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, we presented a letter cue associated with each array and had participants retrieve the learned array while we recorded their scalp activity to examine previously established neural correlates of VWM. We found that an oscillatory correlate (i.e., posterior alpha power modulations, Fukuda, Mance & Vogel, 2015) showed the same set size effect we observed when VWM is used to store new visual inputs. 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 decrease for larger arrays. Furthermore, when participants were asked to retrieve a portion of the learned array (Experiment 2) or asked to retrieve two learned arrays simultaneously (Experiment 3), the alpha power modulation reflected the amount of task-relevant information retrieved from VLTM. These findings suggest that visual information retrieved from VLTM is represented by the same neural dynamics that maintain new visual inputs. This study supports classic theories that propose that when information is retrieved from VLTM it is represented in VWM, similar to new visual inputs.

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22.27, *12:15 pm* **Temporal dynamics of memorability: an intrinsic brain signal distinct from memory** Seyed-Mahdi Khaligh-Razavi[1,2](s.mahdirazavi@gmail.com), Wilma Bainbridge[3], Dimitrios Pantazis[2], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA, [3]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA.

Can we predict what people will remember, as they are perceiving an image? Recent work has identified that images carry the attribute of memorability, a predictive value of whether a novel image will be later remembered or forgotten (Isola et al. 2011, 2014; Bainbridge et al. 2013). Despite the separate subjective experiences people have, certain faces and scenes are consistently remembered and others forgotten, independent of observer. Whereas many studies have concentrated on an observer-centric predictor of memory (e.g. Kuhl et al. 2012), memorability is a complementary, stimulus-centric predictor, generalizable across observers and context. How is memorability manifested in the brain, and how does it differ from pure memory encoding? In this study we characterized temporal dynamics of memorability, and showed that magnetoencephalography (MEG) brain signals are predictive of memorability. We further showed that the neural signature of memorability exists for both faces and scenes; however each of them has its own specific temporal dynamics. Faces showed a persistent memorability signal whereas scenes had more transient characteristics. We also found that neural signatures of memorability across time are different from that of memory encoding, as measured by a post-MEG memory recognition task. This work is the first to measure memorability, as an innate property of images, from electrophysiological brain signals and characterize its temporal dynamics.

Acknowledgement: We would like to thank the 'McGovern Institute Neurotechnology' (MINT) award.

Saturday AM

Saturday Morning Posters

Attention: Inattention

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3001 The role of perceptual similarity in visual search for multiple targets

Elena Gorbunova[1](gorbunovaes@gmail.com); [1]Higher School of Economics, Department of Psychology

The visual search for multiple targets can cause errors called subsequent search misses (SSM) – a decrease in accuracy at detecting a second target after a first target has been found (e.g. Adamo, Cain, & Mitroff, 2013). One of the possible explanations is perceptual set. After the first target is found, the subject becomes biased to find perceptually similar targets, therefore he is more likely to find perceptually similar targets and less likely to find the targets that are perceptually dissimilar. The experiment investigated the role of perceptual similarity in SSM errors. The search array in each trial consisted of 20 stimuli (ellipses and crosses, black and white, small and big, oriented horizontally and vertically), which could contain one, two or no targets. In case of two targets, they could have two, three or four shared features (in the last case they were identical). The features of target stimuli were indicated at the beginning of each trial. Participant's task was to find all the target stimuli or report their absence. Accuracy for conditions with two stimuli with two, three, four shared features and with one stimulus was compared. In case of two targets the correct answer assumed finding both stimuli. Repeated measures ANOVA revealed the main effect of shared features factor, $F(1, 19) = 15.71$, $p = .000$. Pairwise comparisons (with Holm-Bonferroni adjustment) revealed significant differences between all the conditions, except the conditions with one stimulus and two identical stimuli. SSM errors were found for all conditions, except fully identical stimuli condition. The size of SSM effect decreased with increasing the similarity between the targets. The results indicate the role of perceptual similarity and have implications for the perceptual set theory.

23.3002 Inattentional blindness to absent stimuli: The role of expectation

Muge Erol[1](erolm712@newschool.edu), Arien Mack[1], Jason Clarke[1], John Bert[1]; [1]New School for Social Research

Inattentional blindness refers to the failure to see an unexpected stimulus under conditions of inattention. What if an expected stimulus was absent under the same conditions? This study explores the role of attention and expectation in perception using the Mack and Rock (1998) inattention procedure. Observers were asked to report the longer arm of a cross briefly presented in the periphery while simultaneously a color filled circle, alternating between blue and yellow, was present at fixation on every trial except for the critical trials in the inattention, divided and full attention conditions. On the critical trials, after reporting the longer cross arm, observers were immediately asked whether they had noticed anything different. If they responded "yes", they were asked to describe what. If they responded "no", they were also asked to describe what they saw on the last trial. In the inattention condition, only 3 of 15 participants reported being aware that the colored circle was absent. The remaining 12 participants reported seeing either a blue or yellow circle, which, of course, was not there. In the divided attention condition, 7 of the 15 subjects were unaware of the circle's absence and they too thought they saw a colored circle while in the full attention control condition all but one participant were aware of the circle's absence. Clearly there is a significant difference between the awareness of an absent stimulus in the inattention and full attention conditions ($p = .000$, Fisher's exact test). Our results are difficult to attribute to fast forgetting and argue: for the necessity of attention for awareness; against an attention-free phenomenal consciousness, and suggest that attention is not only required to see an unexpected stimulus but also to perceive the absence of an expected one. The results also underline the role of expectation in perceiving.

23.3003 Making the covert overt: Eye-movements reveal the misdirection of gaze and attention

Anthony Barnhart[1](abarnhart@carthage.edu), Francisco Costela[2], Michael McCamy[3], Susana Martinez-Conde[4], Stephen Macknik[4], Stephen Goldinger[5]; [1]Carthage College, [2]Harvard Medical School, [3]Barrow Neurological Institute, [4]SUNY Downstate Medical Center, [5]Arizona State University

The methods of magicians are gaining widespread popularity in cognitive science as a powerful tool for increasing the ecological validity of experiments on attention and perception. In a series of eyetracking experiments, participants watched videos of a magic trick, wherein a coin placed beneath a napkin disappears, reappearing under a different napkin. Appropriately deployed attention would allow participants to detect the "secret" event that underlies the illusion (a moving coin), as it happens in full view and is visible for approximately 550 ms. Nevertheless, we observed high rates of inattentional blindness. Unlike prior research, eye-movements during the critical event showed different patterns for participants, depending on whether they saw the moving coin. By adding a distractor task to the magical presentation, we were able to use it to study the timecourse of divided attention via the measurement of microsaccades. We observed that both the onset and direction of microsaccades index task complexity and the locus of covert attention.

Acknowledgement: NICHD Grant R01 HD075800-01 to Stephen D. Goldinger

23.3004 Are Threatening Unexpected Objects More Likely to Capture Awareness?

Cary Stothart[1](cary.stothart@gmail.com), Daniel Simons[2], Walter Boot[1], Timothy Wright[3]; [1]Department of Psychology, Florida State University, [2]Department of Psychology, University of Illinois at Urbana-Champaign, [3]Department of Psychology, University of Massachusetts Amherst

We sometimes fail to notice unexpected objects or events when our attention is directed elsewhere, a phenomenon called inattentional blindness. Given that threatening objects tend to hold attention longer than non-threatening information, we explored whether unexpected but potentially dangerous objects might be noticed more often. Participants played an online video game in which they tried to dodge missiles that varied in their consequences based on their color; some missiles incurred a large cost and others a small cost. After 5 minutes, an unexpected object appeared and moved across the game screen. Participants (n=360) were somewhat less likely to notice the unexpected object when it shared the same color as the more threatening missiles (M=30%, 95% CI: [23%, 37%]) than when it shared the same color as the less threatening ones (38%, [32%, 46%]), $p = .096$. In a second experiment, participants (n=360) tried to collide with some missiles while dodging others. Noticing of the unexpected object was higher when it shared the same color as targeted missiles (56% [48%, 63%]) than avoided missiles (46% [38%, 53%]), although the difference again was not significant ($p = .058$). Taken, together, these studies suggest that the perceived danger or consequences of an unexpected object have relatively little effect on whether or not people will notice it.

23.3005 Why don't we see the gorilla? Looking in the wrong places, attending to the wrong stuff, or doing the wrong task?

Ruth Rosenholtz[1,2](rruth@mit.edu), Lavanya Sharan[1], Emily Park[3]; [1]Department of Brain & Cognitive Sciences, MIT, [2]CSAIL, [3]Wellesley College

Observers counting basketball passes often do not notice an unexpected "gorilla" (Simons & Chabris, 1999). They notice it more often when counting black-team passes (83%), than white-team passes (42%). Supposedly, when counting black-team passes, the gorilla's similarity to the attended team leads to its capture by attention, and subsequent conscious perception. However, other attentional factors may play a role. We find that: (1) Fixations differ in important ways when counting black vs. white-team passes. "Black-team fixations" land closer to the gorilla (m=6.9 deg horizontal distance) than "white-team fixations" (m=10.0 deg, $t(57)=2.31$, $p=0.02$, display=40x30 deg). (2) However, observers with a known gorilla discrimination task (150 ms presentation of individual video frames) are equally good with either white-team fixations ($d'=2.30$) or black-team ($d'=2.27$). (Umbrella woman $d'>3.25$) (3) Naïve observers (n=11) with white-team fixations, attending to the black team for a numerosity task (static images, 150 ms), rarely notice anything unusual (54%), whereas with black-team fixations (n=10) they often do (80%). These results suggest that attentional selection of similar items is not the whole story. Rather, an interaction between looking the wrong places, and not knowing the "real" gorilla detection task helps render the gorilla invisible. Other recent work, from our lab and others, has questioned the role of selective attention in search; has shed new light on what determines dual-task difficulty; and has ques-

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tioned the notion that certain tasks "require attention", while others do not. We will discuss the implications of these results for what "attention" might mean and how the visual system might adapt to the task at hand.

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23.3006 **Effects of Media Multitasking on Inattentional Blindness during Multiple Object Tracking** Adam Kimbler[1](adamkmblr@gmail.com), D. Alexander Varakin[1], Matt Moran[1], Josh Back[1], Jason Hays[2], Brian Huybers[1]; [1]Eastern Kentucky University, [2]Florida International University

Research suggests that individuals who tend to multitask when consuming media are more easily distracted by task irrelevant stimuli than individuals who rarely multitask (Ophir, Nass, & Wagner, 2009, PNAS). This finding seems to predict that heavy media multitaskers would be more likely to notice a task irrelevant stimulus in an inattentional blindness scenario than light media multitaskers. However, Varakin and Huybers (2014, VSS) found no relationship between media multitasking and inattentional blindness, as measured by Mack and Rock's (1998) paradigm. The current study used the sustained inattentional blindness paradigm, similar to Most et al. (2005). In this task, participants viewed displays of black and white circles and squares moving around on a computer screen, and were tasked with counting the number of times shapes of one color bounce off the edge of the screen. After a few trials performing this task, a critical trial occurred in which an unexpected object (a grey cross) moves across the middle of the screen. Participants (n = 132) also completed the media-multitasking questionnaire (Ophir et al., 2009), which was used to classify them as high (MMI Score greater than 1 SD above mean, n=25), middle-high (score between 0 and 1 SD above the mean, n=37), middle-low (score between 0 and -1 SD below the mean, n=46), and low (score less than -1 SD below the mean, n=24) media multitaskers. Detection rates for the unexpected object were 56% for the high multitasking group, 54% for the middle-high group, 48% for the middle-low group, and 42% for the low group. While the association between media multitasking and detection trends in the predicted direction, it was not significant (□2(3, n=132) = 1.357, p>.05, Cramer's V = .101). Replicating past work, these results suggest that media multitasking is not strongly related to inattentional blindness.

23.3007 **Change detection and recognition memory for objects** Katherine Wood[1](kmwood2@illinois.edu), Daniel Simons[1]; [1]University of Illinois Urbana-Champaign

How can we reconcile exceptional memory for images with findings of change blindness? Although people can remember thousands of scenes or objects with remarkable precision, they often fail to detect changes to small sets of the same objects. We explored whether people can use their detailed long-term memory representations to improve change detection performance. Participants first studied a set of objects and then performed both recognition and change detection tasks for those images. As expected, participants performed better in a two-alternative recognition task than a six-alternative one, although performance was not as accurate as expected based on other recent studies of object memory. In a one-shot change detection task with arrays of six objects, participants performed no better when the presence of a single familiar object in the post-change display indicated the location of the change than when all objects were unfamiliar and provided no additional information about the change; they did not spontaneously use long-term memory to enhance change detection, and in both cases, change detection performance was worse than recognition memory performance. Even when told that any familiar object appearing in the post-change array would be the changed object, meaning that participants could rely exclusively on long-term recognition memory to complete the task, they performed no better than in a change detection task when all items were unfamiliar. When given an explicit strategy to search for a familiar object as a way to improve performance on the change detection task, they performed no better than in the six-alternative recognition memory task. Participants appear unable to combine information from short-term change detection and long-term recognition memory to increase response accuracy beyond that of either task alone.

23.3008 **Exploring moderators of the relationship between working memory capacity and inattentional blindness** Timothy Wright[1](timwright@psy.fsu.edu), Nelson Roque[2], Walter Boot[2], Cary Stothart[2]; [1]Department of Mechanical and Industrial Engineering, College of Engineering, University of Massachusetts Amherst, [2]Department of Psychology, College of Arts and Sciences, Florida State University

Observers sometimes fail to notice seemingly obvious and unobscured events in their visual environment (inattenational blindness; IB). Unfortunately, even though real-world examples of IB can result in dangerous or even fatal consequences, few reliable individual difference predictors have shown success at distinguishing noticers from non-noticers. Even one of the more successful individual difference predictors of IB, working memory capacity (WMC), has not universally demonstrated success despite its hypothesized direct linkage with attentional control. These conflicting findings in the literature may be a result of unknown moderators. For example, through increasing instances in which the location of observer's attention and the unexpected object overlap (central IB), unexpected object salience may moderate the WMC and IB relationship. To test this hypothesis, a large-scale study was conducted on Amazon's Mechanical Turk in which participants completed an automated operation span (AOSPAN) task prior to a sustained IB task. Unexpected object salience and distance from the focus of attention was manipulated between-subjects. Critically, if unexpected object salience moderates the WMC and IB relationship through increasing instances of central IB, a significant relationship would be expected both when the unexpected object is highly salient (a red cross) or when an unexpected object is presented within the focus of attention. Following exclusion criteria, 453 participants' data were analyzed. Overall, no relationship between WMC and IB was observed, even in conditions in which a significant relationship was expected (a highly salient unexpected event or an unexpected object presented within the focus of attention).

23.3009 **Which way is up? Global and local change detection in the hemispheres.** Bonnie Angelone[1](angelone@rowan.edu), Jessica Marcoux[1]; [1]Department of Psychology, College of Science and Mathematics, Rowan University

Hemispheric specialization research suggests lateralized processing between hemispheres. Some of the earliest findings, within language, date back to the mid 1800's (Broca and Wernicke) demonstrating that the left hemisphere is specialized for processing different aspects of linguistics. On the other hand, the right hemisphere seems to be specialized for more spatial tasks. In other research examining complex visual information, performance for global and local stimuli is different depending of the hemisphere of presentation. Typically, there is better performance for global stimuli when presented to the right hemisphere and better performance for local stimuli when presented to the left hemisphere; and this holds true for both linguistic and nonlinguistic stimuli. In addition, this occurs for tasks that focus on memory and perceptual aspects of the stimuli. In the current study we ask whether these findings extend to the ability to detect global and local changes to stimuli presented independently to the hemispheres. In prior VSS presentations from our lab, we used simple shape stimuli that may have led to a crowding effect for some of the trials. Here, participants viewed nonlinguistic stimuli that contained a larger arrow (global) made up of smaller arrows (local). Even though stimuli were not letters, there is the possibility of verbal processing; however, we presented trials very quickly to encourage perceptual decisions. Change and no-change trials were presented in random order; for each change trial either the larger arrow (global change) or the smaller arrows (local change) pointed in a new direction. Also, these changes could have occurred on the right or left side of fixation and participants were instructed not to move their eyes. Preliminary analyses show a global precedence effect overall, but evidence of differential processing of global and local stimuli in the hemispheres in line with the prior literature.

23.3010 **Comparison of 3 intervention approaches into the rehabilitation of hemispatial neglect: an evaluation of short and long term recovery** Monika Harvey[1](monika.harvey@glasgow.ac.uk), Michael Opolka[2], Georg Kerkhoff[3], Hendrik Niemann[4]; [1]School of Psychology, University of Glasgow, Glasgow, UK., [2]Klinik für Neurologie, Ernst-Moritz-Arndt-Universität Greifswald, Greifswald, Germany, [3]Klinische Neuropsychologie & Neuropsychologische Universitätsambulanz, Saar-Universität, Saarbruecken, Germany., [4]Neurologisches Rehabilitationszentrum Leipzig, Bennewitz, Germany

We describe the outcome of a single-blinded randomized comparison of 3 different interventions in sub-acute right hemisphere lesioned stroke patients, suffering from hemispatial neglect. We compared 2 established intervention techniques (Visual Scanning Training (VST) and Optokinetic Stimulation (OKS)) to Visuomotor Feedback Training (VFT). VFT is a relatively unexplored cognitive rehabilitation technique that involves a simple procedure of grasping-to-lift rods at the centre. We evaluated the effectiveness of the 3 approaches in terms of decreased visual neglect symptoms, and possible improvements in activities of daily living, awareness and depression/anxiety, immediately after the training and at a 3 month follow up. Sixty patients were randomised into the 3 groups (VST, N=22; OKS, N=18; VFT, N=22) and each intervention consisted of 10 training sessions conducted over 10 consecutive days, lasting an average of 30 minutes. We

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found that patients in all 3 groups demonstrated a significant reduction of their neglect symptoms accompanied by transfer effects showing significant increases in activities of daily living and awareness as well as reduction in anxiety extending to the 3 months follow up. Although we failed to find significant differences between the 3 interventions, we demonstrate for the first time, that the relatively unexplored intervention of VFT is as effective as the more established rehabilitation approaches of VST and OKS. Moreover, we found further subtle (non-significant) differences between the techniques: For VFT improvements occurred immediately after testing and remained constant at follow up, for OKS greatest improvements seemed to occur between the end of training and follow up, whereas for VST the biggest effects were found straight after training. These are most promising results that can guide future large scale interventions.

Acknowledgement: Chief Scientist Office

Perceptual Organization: Ensemble perception

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3011 Is there a general "statistical module" in visual perception?

Anastasia Belinskaia[1](belinskaya.anastasy@gmail.com), Igor Utochkin[1]; [1]National Research University Higher School of Economics, Moscow, Russia

Observers are good at rapid extraction of summary statistics at a very brief glance at multiple objects. Although this ability is well documented for item numerosity, the average feature or variance in separate domains, less is known about the general cognitive architecture of statistical processing in vision (Haberman, Brady, & Alvarez, 2015). We studied individual differences in the ability to judge different statistical properties to establish whether there can be a single factor affecting the precision of statistical judgments ("statistical module"). Our participants (N = 93, 51 women, mean age = M=19,53) performed three tests requiring them to compare two sets of briefly presented dots to determine which one (1) was more numerous, (2) had larger mean size, or (3) had greater size variability. As size was a relevant dimension, we also evaluated rapid size discrimination in a popout visual search task which required detection of a size singleton in a display similar to our ensemble tasks. Serial visual search for a size target was also added to evaluate whether "statistical abilities" are related to attention. We found in the result a moderate correlation between the accuracy of numerosity and mean judgments (r=.385) but not with variance. All statistics turned out to be correlated with the accuracy of detecting a size singleton (r = .287-.534) and one of serial visual search (r = .238-.438). Overall, these extensive correlations suggest that it can be a low-level factor of individual differences (size discriminability) potentially explaining the observed correlation between number estimation and averaging. It does not require postulating a single "statistical module" in vision. However, additional research is required for more certain claims about this.

23.3012 Ensemble perception omits spatial information about features

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Our visual system rapidly and broadly extracts distributional information about some feature dimensions, such as size, orientation, and hue (Alverez, 2011; Haberman & Whitney, 2012). We tested whether this information could include distributions of those features over space. When viewing a linear blue-to-yellow gradient, can an ensemble process differentiate that pattern from a yellow-to-blue gradient? Our results suggest not. Observers judged the color direction of a gradient created by a set of numerous colored circles. In the briefly flashed display, observers made systematic eye movements towards one 'end' of the gradient (e.g., the yellow end), suggesting that they needed to sample one section of the gradient to know its direction. As a control condition, in half of the blocks we asked observers to instead estimate the number of dots in the gradient. Despite using identical displays, the eye movements disappeared, with fixation remaining much closer to the gradient's center ($t(11) = 5.2$, $p < 0.001$). Judging that yellow is to the right of blue may not be possible via a broad attentional scope. Instead that judgment – or at minimum, storage of the result of that judgment – may require shifting attention to the color of one side (or attentionally localizing the side for a given color).

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23.3013 Ensemble perception under rapid serial visual presentation

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A number of studies demonstrate the important role of ensemble summary statistics in many aspects of visual perception and memory. However, it is still the subject of debate whether attentional resources are involved in the extraction of these statistics. In the present study, we tried to answer this question using the Rapid Serial Visual Presentation (RSVP), a demanding task which is known to produce a temporary processing lapse known as the attentional blink. We modified the paradigm to probe the precision of ensemble representation at different temporal points of AB. 13 participants viewed an RSVP stream of black letters in the center of the screen. One letter in stream was white (it was the first target to be remembered in the AB condition – T1) and followed by a set of white circles. Circle sizes were normally distributed in each trial and their mean size varied from trial to trial. After the stream, participants adjusted a probe circle to the mean size of the set and reported the white letter. The lag between T1 and the set could be 100, 200, 400, or 700 ms. In a control condition, participants were exposed to same stimulation but had to recall only the average ignoring T1. We found that averaging error was high (~30%) at 100- and 200-ms lags and decreased at 400- and 700-ms (~16-20%) in the AB condition. This suggests that attention engaged in processing T1 was diverted from ensemble processing. Surprisingly, the pattern was the same in the control condition. Our speculation is that, despite the instruction to ignore T1, a single white letter in a stream could capture attention involuntarily and produce an AB-like pattern. This speculation needs thorough examination in future studies. Overall, the results of the experiment suggest attentional involvement in ensemble processing.

23.3014 Training Ensemble Perception

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When we glance at a group of people, we can easily discriminate the emotional tenor of the crowd via ensemble perception—a mechanism that allows us to extract gist or summary statistical characteristics from similar stimuli (Haberman & Whitney, 2009). However, some individuals are much more adept at this task than others. Here, we investigated whether it is possible to train participants to improve their sensitivity to overall crowd characteristics. To investigate perceptual learning of summary statistical perception, we trained observers in five sessions of 200 trials, totaling 1000 trials. In each trial, participants viewed a crowd of distinct but similar faces that, collectively, had a randomly determined average expression. Observers adjusted a test face to match the average emotional expression of the crowd. After each response, participants received feedback on their performance, and were awarded points based on accuracy. Across all training sessions, we included a measure to evaluate how many faces in the display participants integrated into their ensemble percept. Additionally, we included a measure to evaluate participants' improvement in single face discrimination. Sensitivity to average crowd expression significantly improved over the five sessions of training. This was accompanied by enhanced integration of information: Participants' accuracy improved as they integrated more and more faces from across the display. Control measures confirmed that participants' improvement cannot be explained by heightened single exemplar recognition or motor improvements associated with the response method. Our results demonstrate that summary statistical perception can be trained and improved. This could yield practical benefits. Individuals who routinely evaluate crowds (e.g. crowd security) can potentially enhance their performance with ensemble coding training. More importantly, these results reveal how ensemble perception improves—through increased integration of multiple exemplars.

23.3015 Inattentional blindness to color ensemble statistics

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The degree to which visual awareness exists outside focal attention is debated. A recent study (Bronfman et al., 2014, Psychological Science) claimed that perception of a particular ensemble statistic, color diversity, does not rely on limited cognitive mechanisms and is therefore perceived "cost free". In a series of experiments, we tested this claim by combining a modified inattentional blindness paradigm with the same color diversity stimuli used by Bronfman et al. Subjects first carried-out a single task in which they attended to a pre-cued row of letters in a Sperling-like display in order to report letter identities. Color diversity of the letters in the uncued rows was manipulated. Then, on the critical trial, a surprise forced choice

recognition test was immediately administered (900ms later) to probe subjects' awareness of color diversity in the unattended rows. Inattentional blindness rates were 78% (experiment 1, N=50), 54% (experiment 2, N=24), and 53% (experiment 3, N=30). These results suggest that conscious perception of color diversity requires attention. Following the critical trial, subjects performed a dual-task on letter identity and color diversity. Letter recall was significantly reduced in the dual-task compared to the single-task, thus demonstrating an attentional cost for perceiving color diversity. We also tested a second ensemble statistic, size diversity, and found similarly high inattentional blindness rates as well as dual-task costs. The present results, along with converging evidence from several recent studies (Cohen et al., 2011; Huang, 2015; Mack & Clarke, 2012; Mack et al., 2015), support the view that conscious perception requires attention, even for easy-to-perceive visual ensemble statistics. In contrast to Bronfman et al.'s (2014) claims, these studies argue that dual-task reportability cannot be cited as evidence of rich conscious perception in the absence of focal attention.

23.3016 Texture Properties Bias Ensemble Size Judgments

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People infer summary properties of scenes, but is this done by statistical aggregation of individuated objects (Alvarez, 2011; Ariely, 2001)? Or could image-level features that do not require any scene parsing—such as local texture (Portilla & Simoncelli, 2000; Balas, Nakano, Rosenholtz, 2009)—better explain the wide range of phenomena attributed to ensembles? If ensemble mean judgments harness parallel pre-attentive mechanisms operating on objects (Chong & Treisman, 2003), then the judgment should be independent of the number of objects being judged. This leads to the prediction that when comparing the mean sizes of objects in two sets, the number of objects in each set should not influence the mean sizes perceived. To test this we presented 6 participants with a two-alternative forced-choice task reporting which of the simultaneously presented sets of circles had the larger mean diameter. Each display could have Equal or Unequal set-sizes. Contrary to the object-based hypothesis, the more numerous set was generally judged to have a larger diameter, biasing the point of subjective equality (PSE) ($t(5)=4.96$, $p=0.004$). While a low-level cue to total area (e.g., luminance in each hemifield) may be sufficient for judgments between equal set-sizes, it does not explain the current data with unequal set-sizes, as this model overestimates participants' PSE shifts ($t(5)=-5.35$, $p=0.003$). Finally, we considered whether performance differences between Equal and Unequal trials could arise from flexibly selecting different strategies. We conclude that this is unlikely because participants' psychometric curves were consistent across blocked (Equal-only or Unequal-only) and intermixed runs. Therefore, we argue that a mid-level representation such as local texture is needed to capture these patterns of behavior in tasks meant to elicit mean size computations. Importantly, these rich summary statistics might encapsulate scene gist—and allow ensemble tasks to be performed well—without representing or measuring objects at all.

23.3017 The Neural Representation of Outliers in Object-Ensemble Perception

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We are sounded by ensembles of objects every day. How are outliers in an otherwise homogeneous ensemble represented by our visual system? Are outliers ignored because they are the minority? Or do outliers alter our perception because their presence changes the nature of an otherwise homogenous ensemble? We have previously demonstrated that ensemble representation in human anterior-medial ventral visual cortex is sensitive to changes in the ratio of two types of objects comprising a heterogeneous ensemble. In the present study we investigated how outliers impact object-ensemble representation in this brain region. In an fMRI-adaptation paradigm, we presented a homogenous ensemble containing 25 identical elements followed by another homogenous ensemble containing a majority of identical elements with 0, 2, or 4 outliers. Observers were asked to ignore the outliers and judge whether the two ensembles were mostly same or different. For same judgments, the majority of the elements in the second ensemble were identical to those in the first, except for the outliers which were visually distinct. For different judgments, the majority of the elements in the second ensemble were distinct from those in the first, except for the outliers which were identical to those in the first ensemble. If outliers can be ignored, there should be adaptation in all same judgement trials and release from adaptation in all different judgement trials. Interestingly, in anterior-medial ventral visual cortex, with just 2 or 4 outliers in the same judgement trials, there was a significant release from adaptation compared to when 0 outliers were present. Moreover, with just 4 outliers in the different judgement trials, there was significant adaptation, comparable to the 0 outlier same judgment trials. Together, these results reveal that outliers significantly impact the perception and representation of otherwise homogeneous ensembles in human anterior-medial ventral visual cortex.

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23.3018 Size averaging is based on distal, not proximal object sizes

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Observers are good at rapid estimation of the average size of multiple objects (Ariely, 2001; Chong & Treisman, 2003). We tested whether the average is calculated along a "raw" (proximal) stimulus size (where only visual angle is important) or relies on the distal size of an object (which requires taking distance information into account). Our participants performed the size averaging task adjusting the size of a probe circle. Using a stereoscope, we changed the apparent distance of ensemble members from the observer. In Experiment 1, all ensemble members shifted by the same disparity angle in both eyes, so that they seemed at different distances but always in one plane. The probe was always in a same plane (zero disparity). We found that presenting ensembles in apparently remote planes made observers to overestimate their mean size in comparison to what is expected from simple visual angle averaging. In Experiment 2, ensemble members were presented at different planes so that (1) visual angle reduced with the apparent distance, making apparent sizes of individual members more similar, (2) visual angle increased with the apparent distance, increasing this apparent dissimilarity, and (3) all members were presented at the zero disparity plane. We found that the mean error in probe averaging in condition (1) was significantly smaller than in other conditions. This finding is in line with previous studies also showing that similarity between ensemble members in one plane reduce the error. As the items in condition (1) could look more similar than in the others only due to the distance cues, we conclude that observers took into these cues into account. Our main theoretical conclusion is that the visual system appears to work with bound objects rather than their separate features when representing their global properties such as the average size.

23.3019 The capacity and fidelity of visual short-term memory for objects and ensembles

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Previous visual working memory (VWM) research suggests that encoding and processing of ensembles is similar to processing of individual objects, and has similar attentional and WM limitations, even though capacity estimates for objects are usually established at 4-5 items, and for ensembles – at 2 structural units. However, available findings do not allow direct comparison of the mechanisms and limitations of object and ensemble encoding, as experimental paradigms used for assessment of VWM for objects and ensembles are distinctly different. We systematically examined VWM capacity and precision for objects and ensembles using two methods, change detection (CD) and continuous report (CR). Participants were briefly presented with sets of 1 to 5 objects or spatially intermixed ensembles of different colors (Experiments 1-3), or ensembles of different colors and shapes (Experiment 4), and tasked to memorize them. During CD task they were asked to identify whether two sequentially presented sets were identical, or the color of one element has changed. During CR task they had to adjust the color of the follow-up probe to match the item previously presented at the same location. In Experiment 1 objects and ensembles were distributed randomly. In Experiment 2 objects were presented at the same distance from the fixation point. In Experiment 3 objects were scaled up to have the same area as ensembles, to control for total retinal stimulation area. Experiment 4 included two CR tasks; in one of the conditions ensembles had another unique feature (shape, irrelevant to the task). We found that VWM estimates for objects and ensembles do not differ significantly within the same set size conditions, nor between the experiments, which is in line with the notion that ensemble representations boost memory capacity for objects, and indicates that there is no decrease in precision when memorizing ensembles, as compared to objects.

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23.3020 **Seeing the mood of the crowd: Ensemble expressions for groups of different identities** Markus Neumann[1,2](markus.neumann@uwa.edu.au), Sarah Griffiths[3], Romina Palermo[1,2], Linda Jeffery[1,2], Gillian Rhodes[1,2]; [1]ARC Centre of Excellence in Cognition and its Disorders, [2]School of Psychology, The University of Western Australia, [3]School of Experimental Psychology, University of Bristol

Humans are often confronted with many faces at once, for example when interacting with a group of people. Compared to seeing a face by itself, processing groups of faces can evoke a different style of information processing, in which people efficiently encode the mean ("ensemble") information of the group. Gaining information about characteristics for an entire group at once might be useful, for example when extracting the average emotion of the crowd at a given moment. Previous research examining ensemble representations of facial expression has been limited because the "groups" contained different expressions of a single person, thus being highly artificial. In the present study, we demonstrate that ensemble representations for expressions can be extracted when faces in the group are of different people. Participants saw happy or angry groups of four face identities with different expression intensities. One individual's face was presented again, either with the exact same expression as seen in the group, or with its intensity shifted towards or away from the average expression of the group. Participants judged whether the expression intensity was the same as it had been in the group. They made errors that were skewed towards the mean expression of the group. These results suggest that people extract an ensemble expression for naturalistic groups of individuals, which biases their memory for individual face expressions. These results extend previous findings by demonstrating that observers encode high-level ensemble information, such as the current mood of a crowd, despite natural variation in a second characteristic, such as the identity of the individual faces in the group. Since crowds experienced outside the laboratory always consist of different people's faces, our findings provide important evidence for the idea that ensemble perception is involved in coding high-level information for groups of faces in everyday life.

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23.3021 **Positive affect worsens ensemble coding performance** Kirsten Ziman[1](Kirsten.k.ziman@dartmouth.edu), Ariana Familiar[2], Won Mok Shim[1]; [1]Psychological and Brain Sciences, Dartmouth College, [2]Department of Psychology, University of Pennsylvania

It has recently been suggested that positive emotions may have flexible effects on the broadening or narrowing of cognitive processing, rather than the fixed, emotion-specific effects previously assumed (Huntsinger, 2013). The effect of mood may be linked to the demands of the present task or the cognitive state which is currently dominant (Huntsinger, Isbell, & Clore, 2014). Our previous finding that subjects utilize a narrowed attentional scope during visual crowding tasks when in a positive (happy) mood supports the notion of a flexible effect of positive states on visual attention, and extends it to low-level visual processing (Familiar, Uddenberg, & Shim, 2015). However, since utilizing a narrowed attentional scope was facilitative in the case of our visual crowding paradigm, it remains unclear if this mood-induced narrowing was task-specific. In the present study, we explore the effects of positive and negative emotions on the perceptual process of ensemble coding (by which viewers encode the visual average of a stimuli set), which is presumably facilitated by a broadened attentional scope. Subjects were shown short video clips to induce positive (happy) and negative (fear) emotions, as well as a neutral control clip. In each emotion condition, subjects were briefly presented with six equally-spaced, pseudo-randomly-oriented peripheral Gabors, immediately followed by a single, centrally-located Gabor. Subjects indicated whether the tilt of the single Gabor was clockwise or counterclockwise relative to the estimated average orientation (ensemble) of the initial six Gabor stimuli. The results show that subjects' estimation of the average orientation was more accurate in the fear condition than in the happy condition. These results provide evidence for a consistent narrowing of one's spatial attentional scope in happy moods across perceptual tasks despite varying task demands, and may point to an emotion-specific narrowing effect of positive states on visual attention processes.

Development: Infancy

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3022 **Brief postnatal visual deprivation triggers longstanding structural reorganization of the visual cortex** Xiaoqing Gao[1](dr.x.gao@gmail.com), Olivier Collignon[2], Adélaïde de Heering[3], Terri Lewis[4,5], Hugh Wilson[6], Daphne Maurer[4,5]; [1]Institute of Research in Psychology/Institute of Neuroscience, University of Louvain, Louvain-la-Neuve, Belgium, [2]Centro Interdipartimentale Mente/Cervello (CIMeC), Università di Trento, Mattarello, Italy, [3]UNESCOG, Université Libre de Bruxelles, Bruxelles, Belgium, [4]Department of Psychology, Neuroscience & Behaviour, Hamilton, Canada, [5]The Hospital for Sick Children, Toronto, Canada, [6]Centre for Vision Research, York University, Toronto, Canada

What role does early visual experience play in the development of the visual cortex? Animal models have demonstrated that transient visual deprivation early in life permanently alters the response properties of neurons in the visual cortex (Wiesel & Hubel, 1965). In humans, studies with blind adults suggest a critical role of early visual experience in shaping the visual cortex. Early but not late onset of blindness causes a massive reduction of grey and white matter volume in the early visual areas (Noppeney, 2007). However, it remains unclear if a transient period of postnatal visual deprivation is sufficient to trigger a long-lasting reorganization of the visual cortex. Here, we obtained high-resolution anatomic MRI scans from a unique cohort of adult patients (n=10) who were deprived of all patterned visual input early in life (mean length of visual deprivation=143 days, range=65-238 days) as a result of congenital dense central cataracts in both eyes. Compared to age and sex matched controls (n=19), the cataract-reversal patients showed increased cortical thickness in the left pericalcarine sulcus and right parstriangularis ($ps < 0.001$) and decreased cortical thickness in the left lingual gyrus, left superiortemporal sulcus, right temporal-parietal junction, right isthmuscingulate, right parsopercularis, and right lingual gyrus ($ps < 0.001$). Within the visual cortex, such changes seem to be reciprocal: the thickening in the left pericalcarine sulcus was highly correlated with the thinning in the left lingual gyrus in cataract-reversal patients ($r=-0.59$, $p=0.036$) but not in controls ($r=-0.22$, $p=0.18$). The reduced visual acuity of cataract-reversal patients could not account for the changes in cortical thickness in any of these areas. Thus, early visual deprivation does trigger a long-lasting cortical reorganization, possibly through competitive interactions among cortical regions.

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23.3023 **Infants' Dynamic Accommodation and Vergence Tracking of an Unpredictable Stimulus** T. Rowan Candy[1](rcandy@indiana.edu), Eric Seemiller[1], Colin Downey[1], Lawrence Cormack[2]; [1]Vision Science & Optometry, Indiana University, [2]Department of Psychology & Center for Perceptual Systems, The University of Texas at Austin

Typical development of the binocular visual system requires focused and aligned retinal images. These image attributes are defined by accommodation and vergence motor responses in the habitual environment. We have shown that these motor responses are sensitive to less than 0.50 D or MA of target movement by 3 months of age in human infants (Wang & Candy, 2010; Seemiller et al., 2015). The purpose of this study was to move from spatial sensitivity into addressing the temporal characteristics of these systems in early infancy, using an eye movement correlogram approach (Mulligan et al., 2013). Infants and adults were presented with a stimulus moving randomly in depth on a motorized track. The target was a cartoon movie with naturalistic spatial amplitude spectra, moving randomly over distances between 33 and 80cm from the participant. Eye position and refractive state were recorded binocularly and simultaneously at 50Hz using eccentric photorefraction and purkinje-image tracking analyses of video images (PowerRefractor, PlusOptix). Functionally emmetropic adults and typically developing infants aged from 8 to 17 weeks watched these stimuli for 20 and 45s trials. The time series of the responses and their cross-correlograms with the stimulus were then examined. Adult responses were consistent with the literature; both vergence and accommodation were tightly coupled with the stimulus and with each other. Infant vergence responses tended to be more robust than their simultaneously recorded accommodation responses for these unpredictable dynamic stimuli and viewing distances. Vergence responses were

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more variable than in adults, while accommodation was more variable still, and often seemingly uncoupled from vergence. These data suggest that the vergence system is more responsive than the accommodation system during the first months of postnatal development, and that accommodative convergence is not the primary drive to vergence in this period.

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23.3024 **Emergence of implied motion perception in human infants**

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A previous study reported that infants aged 5-8 months significantly shifted their gaze toward the direction of a person's dynamic actions such as running depicted in a still image (Shirai & Imura, 2014, Experimental Brain Research). This suggests that even young infants have the ability to perceive dynamic events depicted in still images (implied motion perception, cf. Kourtzi, 2004, Trends in Cognitive Sciences). In the present study, we tested whether younger (4- and 5-month-old) infants show the similar gaze behavior to a dynamic action depicted in a still image. Sixteen 4-month-old infants and 16 5-month-old infants participated in the experiment. At the beginning of each experimental trial, a still image of an adult male model running toward either the left or right side was presented shortly (duration = 600ms) on the center of a CRT monitor (the running-cue condition). Two identical black discs subsequently appeared on the right and left side of the CRT monitor simultaneously. Each infant took part in 20 trials. Infants' visual preference for a black disc, which consistently appeared on the same side as the running direction of the still image, was measured (forced-choice preferential looking method: Teller, 1979). Results showed that the 5- but not 4-month-old infants showed significant visual preference for the cued disc. Additionally, when the still image was replaced with a picture of the same model standing and facing either left or right side (the standing-cue condition), both the younger and older infants showed no significant visual preference for the cued disc. These results indicated that implied motion perception emerges between 4 and 5 months of ages in human infants.

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23.3025 **Infants can recognize the lightness change in cast shadows**

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When an object goes through cast shadows, humans perceive that the object's lightness becomes darker because the object's light sources are blocked. This observation suggests that adults perceive the change of an object's lightness in shadows based on the assumption that the surface of an object is darker when in shadows. In the current study, we investigated whether 5- to 8-month-old infants also use this assumption to perceive the lightness of the object's surface in shadows. In Experiment 1, we created a CG movie of a duck going through cast shadows. In this movie, the lightness of the duck's surface was darker while the duck was within the two shadows. We then created an "unnatural movie" in which the lightness of the duck's surface inside and outside of the shadows was reversed. If infants, like adults, use the "shadow assumption" to perceive the object's lightness in shadows, the infants would detect the unnatural lightness change. We compared infants' looking preference for the natural and unnatural movies and tested their preference for the unnatural movie using Csibra (2001)'s method. Our results showed that 7- to 8-month-olds preferred the unnatural movie, but 5- to 6-month-olds did not show this preference. The results revealed that only 7- to 8-month-old infants could detect the unnatural change of the lightness of the duck's surface. In Experiment 2, we created a movie without shadows to examine whether infants' preference in Experiment 1 was based on just a lightness change without context. We used the same procedure as in Experiment 1 and the results showed that no infants showed any preference in Experiment 2. These results suggest that 7- to 8-month-old infants do perceive an object's lightness with the assumption that the surface of an object is darker when in shadows.

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23.3026 **The specificity of labels differentially impacts infants' attention-related visual strategies and neural responses**

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During the first year of life, learning that an individual-level label corresponds to an object or face increased visual differentiation of within-group exemplars (Scott & Monesson, 2009; Scott, 2011). The present study sought to follow-up these results and determine whether individual-level training differentially impacted infants' attention-related visual strategies and neural responses. Here, six-month-old infants were trained for three months with storybooks containing novel objects labeled either with category-level or individual-level names. Before and after training infants' visual fixation location and duration toward serially presented objects was assessed with an eye-tracker. This was followed by an examination of infants' event-related potentials (ERPs) during an oddball task. Total dwell time to the top and bottom half of untrained exemplars within the trained group were examined before and after training and across groups. Analyses suggest that infants fixated the untrained images longer at 9 months compared to at 6 months, $F(1, 20) = 5.82$, $p < .05$. This main effect was qualified by an interaction between age and group, $F(1, 20) = 4.82$, $p < .05$ which was driven by a significant increase in looking from 6 to 9 months for the individual-level group but not the category-level group, $p < .05$. ERP analyses revealed a greater Nc amplitude in response to infrequent versus frequent objects, $F(1,40) = 5.80$, $p = .02$, which was qualified by a 3-way interaction. The 3-way interaction, $F(1,40) = 4.51$, $p = .04$, was driven by a larger Nc amplitude to infrequent relative to frequent objects, but only for the 9-month-old infants trained with individual-level labels ($p= .003$). No amplitude differences were found after category-level training. Our findings extend past training work by demonstrating that infants use labels to shape the specificity of their perceptual representations and that individual-level labels differentially increases attention relative to category-level labels.

23.3027 **Developmental changes in infants' attention to naturalistic faces and visual saliency**

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Previous studies have demonstrated that faces increasingly capture infants' visual attention over the course of the first year of life. However, since most studies have used relatively simple stimuli, far less is known about the developmental changes in attention to faces in more naturalistic contexts and the degree to which infants prefer faces over competing visual information (e.g. low-level saliency). In the current study, remote eye-tracking techniques coupled with a free-viewing paradigm were adopted in order to investigate the development of more naturalistic visual orienting toward socially meaningful stimuli. Infants from two longitudinal cohorts (cohort one: 3.5, 5, 6.5 months; cohort two: 6, 8, 10, 12 months) and adults were presented with nine naturalistic videos which displayed three characters performing baby-friendly actions, such as waving a balloon or dancing with a toy. By establishing a face model, which assumed that attention would be directed toward locations containing faces, and a saliency model, which assumed that fixations would be driven by regions of high saliency, the predictive power of each model in determining fixation locations was evaluated. As predicted, the saliency model was a significantly better fit only for the youngest age group (3.5 months). Although neither model was a better predictor for fixations of infants aged 5 and 6.5 months (cohort one) or 8 months (cohort two), the 6-month group (cohort two) looked significantly more at faces than salient regions. This suggests that 5 to 8 months is a transition point at which individual differences in attention to faces may be high, possibly due to differences in the development of executive function and inhibitory control across individuals. The face model better accounted for fixations of 10- and 12-month-old infants and adults, suggesting that a clear face preference was established toward the end of the first year.

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23.3028 **Infants' recognition of caricature of mother's face**

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Saturday AM

In adult studies, caricature effect has been reported. For example, adults can identify more quickly face caricatures, which were produced by exaggerating all metric differences between a face and a norm, than veridical line drawings and anti-caricatures (Rhodes et al., 1987). These caricature advantages were found only in familiar face recognition (Rhodes & Moody, 1990). These findings suggest that we encoded familiar faces as distinctive feature deviations from a norm, and our representation of familiar faces are schematized and exaggerated like caricatures. The current study examined whether infants would show the caricature effect in familiar face recognition. We used a preferential looking procedures to investigate the discrimination between their own mother's face and stranger's face in infants aged 6 to 8 months. We presented infants' own mother's face and a stranger's face side by side, and tested their visual preference for mother's face than a stranger's face in the three conditions; photographs, caricatures, and line drawings. We analyzed the data only in infants who showed the preference for their own mother's face in photographs. We found that 7- and 8-month-old infants maintained significant preference for their own mother's face than a stranger's face in caricatures ($p < .05$), but not in line drawings. On the other hand, 6-month-old infants did not show any preference for their own mother's face both in caricatures and line drawings. In sum, 7- and 8-month-old infants, but not 6-month-old infants, showed the caricature effect in recognition of their own mother's face. Our results suggest that the ability to utilize exaggerated features to recognize familiar faces would develop around 7 months of age.

Acknowledgement: This research was supported by COI STREAM (Center of Innovation Science and Technology based Radical Innovation and Entrepreneurship Program), Ministry of Education, Culture, Sports, Science, and Technology, Japan, a Grant-in-Aid for Scientific Research from JSPS (26285167), and a Grant-in-Aid for Scientific Research by JSPS Research Fellowships for Young Scientists (25).

23.3029 Accounting for cognitive effort in a visual working memory task in 13- and 15-month old infants Chen Cheng[1](chencheng.psy@gmail.com), Zsuzsa Kaldy[1], Erik Blaser[1]; [1]Department of Psychology, University of Massachusetts Boston

Introduction. Development brings improvements in visual working memory performance, but it is not clear whether this is caused by an increase in memory capacity per se, or by increases in cognitive effort and/or task engagement. Through pupillometric measures and behavioral coding of task engagement during a Delayed Match Retrieval task (Kaldy, Guillory, & Blaser, 2015), we sought to tease these factors apart. Method. Two groups of infants (younger, mean age = 13.6 months, and older, mean age = 15.5 months; N=16) performed 12 trials of an object-location binding task requiring anticipatory looks to the remembered locations of matching (virtual) cards. We video-recorded participants while a Tobii T120 eye-tracker monitored gaze and pupil dilation. Subsequently, three observers (blind to the events on the screen) scored infants' disengagement by timing periods when the infant looked away from the screen. Cognitive effort was measured through phasic, task-evoked pupil responses. Results. As expected, older infants significantly outperformed younger infants on the memory task ($F(1,15) = 7.422$, $p = .015$). This age difference could not be explained by disengagement episode counts ($F(1,15) = .996$, $p = .33$) nor accumulated disengagement time ($F(1,15) = 1.449$, $p = .247$). However, pupillometry revealed significantly greater task-evoked responses in the older group during the critical 'encoding' phase of the memory task, when to-be-remembered stimuli were presented (see supplemental material). Conclusion. Our results show that cognitive effort, as measured by task-evoked pupil responses, is likely a better predictor of performance than more global measures of disengagement, such as looks away from the screen. Further pupillometric analyses will enable the precise quantification the role of cognitive effort in infants' visual working memory performance.

Face Perception: Individual differences

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

23.3030 The diversity, prevalence, and stability of idiosyncratic eye-movement patterns to faces Joseph Arizpe[1,2,3,4](Jarizpe@uthsc.edu), Galit Yovel[5], Chris Baker[1]; [1]Section on Learning and Plasticity, NIMH, NIH, [2]Institute of Cognitive Neuroscience, University College London, [3]Neurology Dept., University of Tennessee Health Science Center, [4]Le Bonheur Children's Hospital, [5]School of Psychological Sciences, Tel Aviv University

The spatial pattern of eye-movements to faces considered as typical for neurologically healthy individuals is a roughly T-shaped distribution over the internal facial features with peak fixation density tending toward the left eye (observer's perspective). However, recent studies have indicated that striking deviations from this classic pattern are common within the population and are highly stable over time, revealing that this classic pattern actually reflects the average of various idiosyncratic eye-movement patterns across individuals. To investigate the prevalence of different idiosyncratic patterns within the healthy population, we analyzed the spatial patterns of eye-movements for 48 participants to estimate the range and frequency of different kinds of individual eye-movement patterns to faces. We found that there was a rather continuous variability among our participants' patterns; however, some clustering among similar idiosyncratic patterns could be discovered. In accord with prior studies, we could not find any relationship between particular idiosyncratic eye-movement patterns and recognition performance. Finally, to determine the stability of idiosyncratic eye-movement patterns across various experiment factors, we examined how Race of Face, Face Orientation, pre-stimulus Start Position, study or test Phase, and Time Window modulated the relative distinctiveness among and consistency within individual spatial patterns of eye-movements to faces. Our findings raise interesting questions regarding whether and how such differential eye-movement patterns may relate to individual differences in information utilization and neural processes underlying the cognitive processing of faces and, indeed, all visual stimuli.

23.3031 Fixation sequence consistency during face identification Yuliy Tsank[1](yuliy.tsank@psych.ucsb.edu), Miguel Eckstein[1]; [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara

When performing face discrimination tasks (i.e. identification, gender discrimination etc.) using multiple saccades, humans use idiosyncratic fixation strategies (Kanan et al. 2015; Mehoudar et al. 2014; Peterson and Eckstein, 2012; Walker-Smith et al. 1977). Here we analyze observers' consistent use of their preferred fixation sequence across trials during face identification and investigate its relationship to perceptual performance. Methods: Fifty five observers completed a 1 of 10 face (15 deg) identification task in white luminance noise. Observers made free eye movements in varying numbers of blocks of 125 trials each (125 - 1500 trials total) with a face viewing time of 1500ms. Each of the 10 faces were divided into 10 areas of interest in order to assign a number (1-10) to each fixation position. We analyzed the similarity of fixation sequences across trials corresponding to specific faces within a subject using only the first 3 fixations from each trial. We used the Needleman-Wunsch algorithm (Scanmatch, Cristino et al. 2010) to obtain a similarity score for fixation sequences between trials. Results: Fixation sequences that included foveating the eyes as well as an area that is centered between the eyes and nose were the most common and represented 12% of all trials across observers. Consistent use of individual-specific fixation areas varied across observers from 8% to 50% of all trials. Critically, we show that observers that consistently use more similar fixation sequences achieve higher performance in the task ($r = 0.4$; $p< .01$). Conclusion: Our results extend previous findings on variations across individuals in fixation strategies to faces. The present findings suggest that consistent use of a preferred idiosyncratic fixation sequence also varies greatly across individuals and that observers with greater consistency achieve higher perceptual performance.

23.3032 Eye movements during challenging cultural group identification of faces Puneeth Chakravarthula[1](chakravarthula@psych.ucsb.edu), Miguel Eckstein[1]; [1]Department of Psychological and Brain Sciences, UCSB

Initial fixations are critical in acquiring most of the information supporting face identification (Hsiao et al., 2008; Or et al., 2015). Preferred initial eye movements for a majority of humans are directed to points just below the eyes which vary moderately across tasks (identity, gender and emotion; Peterson et al., 2012). Here, we compare the perceptual performance and initial eye movements of Indian and Caucasian observers in a difficult cultural group identification task: North vs. South Indians. Methods: An in-house image data set of North and South Indian faces was created in India by verifying the heritage of the photographed individuals. Indian and Caucasian observers were presented with a face from the image set (90 North and 90 South Indian faces) for 1.5 s. and categorized the face as North or South Indian. Each face was shown twice across 4 sessions with 90 trials each. At the beginning of each session the subjects were allowed to study, for 1 minute, a total of 12 North and 12 South Indian faces (not included in the main study) with ground truth. There was no feedback during the experiment. Results: Average perceptual accuracies identifying the cultural group of the faces were significantly higher for the Indian

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observers (60 ± 1.5 %) relative to the Caucasian observers, who were at chance (50 ± 1.8 %). However, there initial points of fixation across Indian and Caucasian observers were similar with both groups looking to a point just below the eyes. Conclusions: Our results suggest that initial preferred points of fixation for identifying the cultural group of a face might be similar to those for determining the identity of a face. The difference in accuracy identifying the cultural group across Indians and Caucasians cannot be attributed to variations in strategy in the preferred initial fixations.

23.3033 Gaze behavior provides a gender fingerprint Antoine Coutrot[1](a.coutrot@ucl.ac.uk), Nicola Binetti[2], Charlotte Harrison[2], Isabelle Mareschal[3], Alan Johnston[1,2,4]; [1]CoMPLEX, University College London, UK, [2]Department of Experimental Psychology, University College London, UK, [3]School of Biological and Chemical Sciences, Queen Mary University of London, UK, [4]School of Psychology, University of Nottingham, UK

The human face is central to our social interactions, as it allows us to form judgements about identities, intentions, and emotions. Recent studies have shown that, while gazing at faces, each one of us has a particular eye-scanning pattern that is highly stable across time. Although some variables such as culture or personality have been shown to modulate gaze behaviour, we still don't know what shapes these idiosyncrasies. Here we demonstrate that the gender of both the participant (gazer) and the person being observed (actor) strongly influence gaze patterns during face exploration. We make use of the largest set of eye tracking data recorded (405 participants, 58 nationalities) from participants watching videos of another person. Exploiting advanced data-mining techniques, we build a data-driven model able to encapsulate the highly dynamic and individualistic dimension of a participant's gaze behaviour. Female gazers follow a much more exploratory scanning strategy than males, who focus on the eye region. Moreover, female gazers watching female actresses look more at the eye on the left side. This result has strong implications in every field using gaze-based models, including the diagnosis of disorders such as Autism, where a substantial sex ratio difference exists. We also show that a classifier solely trained with eye tracking data is able to identify the gender of both the gazer and actor with very high accuracy. The finding that a gender fingerprint can be extracted from how people observe others reveals widespread, stereotypical face scanning behaviours that fundamentally differ between men and women.

23.3034 Why do better face recognizers use the left eye more? Simon Faghel-Soubeyrand[1](simonsoubeyrand@gmail.com), Nicolas Dupuis-Roy[1], Frédéric Gosselin[1]; [1]Dept of Psychology, University of Montreal

Blais et al. 2013 showed that the best participants in a facial emotion recognition task used the left eye of face stimuli more than the other participants. By inducing the use of the left or the right eye in different subjects, Gosselin et al. 2014 demonstrated that left-eye usage caused better face recognition. We hypothesized that this effect may result from the right hemisphere face processing superiority (e.g. Voyer et al. 2012). In Experiment 1, we replicated Gosselin et al. (2014) using a different induction method and a more controlled setting. Specifically, we induced the use of the left (N=15) or the right eye (N=15) during a gender discrimination task by eliminating the gender-diagnostic information from the other eye. Group classification images revealed that the informative eye was the only region significantly used ($p< .01$, Cluster test). Performance, as indexed by the number of bubbles required to reach 75% of correct responses, was not different in the two subject groups before ($p=.5$) or after ($p=.13$) the induction but the left-eye group performed significantly better than the right-eye group ($F(1,28)=6.38$, $p=.01$) during the induction. In Experiment 2, we examined whether this left eye performance effect is related to the right hemisphere face processing superiority. Twenty subjects did the same face gender categorization task as in Exp.1 except that an eye-tracker (Eyelink II, 250Hz) was used to enforce fixation at the center of the screen and that the induced eye was presented 2.2 deg to the left, to the right or under the fixation cross. Results show, as in exp.1, more efficient face processing for left-eye than for right-eye subjects, but only when faces were presented to the left and under the fixation cross ($F(1,113)=16.81$, $p< 0.001$ and $F(1,113)=5.75$, $p=0.01$ respectively), corroborating the right hemisphere face processing superiority hypothesis.

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23.3035 Individual differences in creation of forensic composite faces: A comparison of multiple systems Rachel Bennetts[1](rachel.bennetts@gmail.com), Shobonna Akhter[1], Kayleigh Ziegler[1], Charlie Frowd[2]; [1]Department of Psychology, Bournemouth University, [2]Department of Psychology, University of Winchester

Lab-based research has found that people vary widely in their ability to recognise faces. However, few studies have examined how these individual differences relate to performance in more ecologically valid face recognition tasks. Eyewitnesses to a crime are sometimes asked to generate an image of the suspect using specialised software systems – these are known as "composite" face images. To date, no research has examined whether the face recognition ability of the witness affects the quality of the composite, or whether certain systems are better suited to individuals with high or low face recognition ability. This study examined composite face creation in 60 individuals with high, medium, and low face recognition ability, as measured by performance on a standard laboratory test of face memory (the CFMT). Each participant watched a video of a single unfamiliar face (randomly selected from a group of 10 faces), and created a composite image of the face 2-4 hours later. Participants were randomly assigned to one of two commonly used composite systems – ProFit, which asks individuals to select and manipulate individual facial features; and EvoFit, which encourages more holistic processing by asking individuals to select faces based on their overall appearance. A second group of participants (n = 51) rated the composites for their likeness to the original faces. There was no overall difference in likeness ratings for high and low face memory composites. However, there was a significant interaction between face memory ability and composite system: participants with high face memory created better composites with the EvoFit system, whereas participants with low face memory created better composites with the ProFit system. The results indicate that variability in face recognition ability can have significant real-world effects. The findings are also in line with previous work suggesting a link between face recognition ability and holistic processing.

23.3036 Broadly Superior: Many, but not all, visual and non-visual abilities are strong in face super-recognizers Sarah Cohan[1](sarahc@wjh.harvard.edu), Ken Nakayama[1], Brad Duchaine[2]; [1]Psychology, Harvard University, [2]Psychology, Dartmouth College

Super-recognizers have extraordinarily good face identity recognition, and their abilities have proven useful for law enforcement (Davis, Jansari, & Lander, 2013). Previous work has demonstrated that they excel with face identity perception judgments (Russell et al., 2009) as well as discrimination of faces based on shape and surface reflectance (Russell et al., 2012). However little is known about their broader cognitive and perceptual abilities. As a result, the scope of their "super powers" is unknown. To investigate this issue, we tested a group of 17 super-recognizers with the Wechsler Abbreviated Scale of Intelligence (WASI) and a battery of tests assessing 1) perception of face expression, age, and sex, 2) sequential matching of objects and bodies, 3) recognition of cars, common objects, and abstract art, 4) memory for unfamiliar music, environmental sounds, and word pairs, 5) digit span, 6) multiple object tracking, and 7) change detection. On the four WASI subtests, the z-scores for the super-recognizers were .33 (Block Design), .59 (Vocabulary), .26 (Matrix Reasoning), and .39 (Similarities), so their general intelligence is not extraordinary. In contrast, aside from a few tests, their average scores on the battery were quite strong. Average z-scores on nearly all the face tests were greater than 1.0, as were their scores for car and abstract art memory. Surprisingly, some non-visual abilities were also well above average: the average z-score was nearly 1.5 for the verbal paired associates test and 0.9 for digit span. Overall, these results demonstrate super-recognizers have numerous perceptual and cognitive strengths. However their normal scores on the WASI and several other tests show that their abilities are not uniformly excellent and indicate that their many strengths do not result from general test-taking skills. The factors generating the variability in their abilities are unclear and present a challenge for future research with super-recognizers.

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23.3037 A common factor may underlie personality traits and both neural and perceptual responses to emotional faces Katie Gray[1](k.l.h.gray@reading.ac.uk), Freya Lygo[2], Miaomiao Yu[2], Daniel Baker[2]; [1]School of Psychology, University of Reading, [2]Department of Psychology, University of York

Saturday AM

Difficulties in interpreting emotional faces are often linked with autistic traits and alexithymia. Yet it is unclear whether these problems are due to reduced neural processing of faces, or differences in decision strategies in perception experiments. To measure neural responses, we adapted a steady-state EEG paradigm (Liu-Shuang, Norcia & Rossion, 2014, Neuropsychologia, 52:57-72) for emotion detection. Random identity neutral faces were presented periodically (at 5Hz) with 'oddball' targets appearing every fifth cycle (at 1Hz). The targets were emotional faces of six emotions (angry, happy, sad, fear, disgust, surprise), morphed along a continuum relative to neutral (0, 6, 12, 24, 48, 96 and 144% emotional intensity). Lateralised occipito-parietal responses at harmonics of the oddball frequency (2, 3 & 4Hz) increased monotonically with morph level for 24 observers, and showed substantial individual variability that was unrelated to the baseline response at the flicker frequency. Observers also completed a 2IFC experiment using the same temporal parameters as the EEG experiment. Observers were presented with a target stream containing a single emotional face embedded within 8 neutral distractors, and a null stream containing only neutral faces, and asked to indicate which stream contained the emotional target. Accuracy increased as a function of morph level, and 75% correct thresholds were estimated from the psychometric functions. Inverting the faces significantly reduced detection performance and EEG responses. We also measured autism quotients and alexithymia using standard scales, and found a typical level of correlation between these measures ($r=0.61$, $p< 0.01$). Alexithymia correlated with psychophysical thresholds ($r=0.49$, $p< 0.05$), whereas autistic traits correlated negatively with maximum EEG amplitudes ($r=-0.50$, $p< 0.05$). Principal components analysis of all four variables identified a single factor with high loadings for each measure. These results suggest that personality differences are predictive of both neural responses to, and perceptual experience of, emotional expression.

23.3038 **Individual differences in the contribution of shape and texture to the recognition of personally familiar faces** Jürgen Kaufmann[1,2](juergen.kaufmann@uni-jena.de), Marlena Itz[1], Stefan Schweinberger[1,2]; [1]Department of General Psychology and Cognitive Neuroscience, Friedrich Schiller University, Jena, Germany, [2]DFG Research Unit Person Perception, Friedrich Schiller University, Jena, Germany

It has been suggested that texture information contributes more to familiar face recognition than shape. In two experiments, we tested effects of reduced identity information in either shape or texture on the recognition of personally familiar faces. Stimuli were derived from images taken with a 3D camera system, and both behavioural data and event-related potentials (ERPs) were analysed. In Experiment 1, participants performed a face familiarity task on images of five personally familiar and five unfamiliar faces, respectively. All faces were shown as i) original images (i.e. including both shape and texture information), ii) "shape-only" stimuli (shape "masks" based on the 3D vertices), and iii) "texture-only" stimuli (i.e. flattened surface maps). Performance was best for original faces, followed by "texture-only" stimuli, and worst in the "shape-only" condition. The N250 familiarity effect was largest for original faces and non-significant for "shape-only" stimuli. Experiment 2 used a similar design, with the only difference that "shape-only" stimuli now consisted of the individual face shape combined with an average texture, and "texture-only" faces showed individual texture combined with an average shape. Again, performance was best for original images, followed by "texture-only", and worst for "shape only" faces. In contrast to Experiment 1, significant N250 familiarity effects were found for all three face conditions, but the effect was smallest for "shape-only" stimuli. Furthermore, performance and ERP familiarity effects for all conditions correlated positively with scores in a face learning (Cambridge Face Memory Test, CFMT), and also with a famous face recognition test (Bielefelder Famous Faces Test, BFFT). Overall, our results suggest that recognition of personally familiar faces is mainly, albeit not exclusively, driven by texture information, and that good recognizers are characterized by a larger processing flexibility, possibly enabling them to cope better with reduced identity information in either dimension.

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23.3039 **For best results, use the eyes: Individual differences and diagnostic features in face recognition** Jessica Royer[1](royer.jessica91@gmail.com), Caroline Blais[1], Karine Déry[1], Daniel Fiset[1]; [1]Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais

In recent years, the interest in individual differences in face processing ability has skyrocketed. In fact, individual differences are quite useful in better understanding the mechanisms involved in face processing, since it is thought that if a certain mechanism is important for this task, individual efficiency in using this mechanism should be correlated with face processing abilities (Yovel et al., 2014). The present study investigated how variations in the ability to perceive and recognize faces in healthy observers related to their utilization of facial features in different spatial frequency bands. Fifty participants completed a 10 choice face identification task using the Bubbles method (Gosselin & Schyns, 2001) as well as six tasks measuring face and object recognition or perception ability. The individual classification images (CIs) obtained in the bubbles task were weighted using the z-scored performance rankings in each face processing test. Our results first show that the utilization of the eye region is correlated with performance in all three face processing tasks, ($p< .025$; Zcriterion=3.580), specifically in intermediate to high spatial frequencies. We also show that individual differences in face-specific processing abilities (i.e. when controlling for general visual/cognitive processing ability; Royer et al., 2015) are significantly correlated with the use of the eye area, especially the left eye ($p< .025$; Zcriterion=3.580). Face-specific processing abilities were also significantly linked to the similarity between the individual and unweighted group CIs, meaning that those who performed best in the face recognition tests used a more consistent visual strategy. Our findings are congruent with data revealing an impaired processing of the eye region in a prosopagnosic patient (e.g. Caldara et al., 2005), indicating that the visual strategies associated with this condition are also observed in individuals at the low-end of the normal continuum of face processing ability.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

23.3040 **Perceptual challenges for inverted icons: The Face Inversion Effect does not extend to complex objects** Carrie Melia[1](c-melia04@gmail.com), Michael Hout[1]; [1]Department of Psychology, New Mexico State University

The face inversion effect (FIE) is the phenomenon whereby inverted faces are harder to recognize than are upright instances of the same face (Yin, 1969). We sought to determine if two aspects of faces that may be shared by other objects can contribute to the FIE. First, faces are perceptually complex; other complex items might therefore elicit inversion effects. Second, faces are seldom encountered upside-down, limiting the extent to which top-down processing can be used when they are encountered in an inverted fashion. We investigated if the degree of visual complexity and plausible inversion of objects could produce (and explain) analogous results to those obtained with faces. In a pilot experiment, we showed naïve participants object categories, and asked them to rate items on 1) visually complexity, and 2) likelihood of being encountered upside-down. We then identified six categories varying in visual complexity (simple, complex) and plausible inversion (rarely, occasionally, and often found upside-down). For instance, remote controls were rated as visually complex, and likely to be found upside-down. Male and female faces were also included. Participants (N=44) first saw a cue, followed by a pair of category-matched exemplars, quickly indicating which picture matched the cue. Cues were upright or inverted, and the pair of pictures either matched or mismatched the orientation of the cue. Difference scores were calculated by subtracting the RT for trials with upright cues from those for inverted cues. Thus, positive values indicated costs for inversion. For object stimuli, there was no main effect of match condition, visual complexity, or plausible inversion, and there were no significant interactions. However, face data showed a clear FIE, replicating prior work. It appears that the FIE is unique to faces, and does not extend to visually complex, orientation stable categories.

23.3041 **Attachment Avoidance and Visual Attention for Emotional Faces over Time** Shayne Sanscartier[1], Jessica Maxwell[1], Eric Taylor[1], Penelope Lockwood[1]; [1]Psychology, University of Toronto

Research suggests that attachment avoidance (discomfort with intimacy and closeness) alters the way the visual system processes emotional faces (Zhang, Li, & Zhou, 2008). Because they are uncomfortable with emotion, avoidant individuals are thought to disengage their attention from negative emotional faces (Dewitte, 2011). Conversely, they may be hypervigilant to emotional faces in the early stages of face processing (Dan & Raz, 2012). The current study was designed to test both the hypervigilance and the disengagement hypotheses. Participants were asked to complete a two-alternative forced choice task, with a face fixation and varying stimulus-onset asynchronies (SOA), to determine whether avoidant individuals differently attend to emotional faces over the course of emotional face processing. Participants were presented with happy, fearful, neutral and inverted faces. After a variable SOA (i.e., 0ms, 150ms, 300ms, 450ms, 600ms, 750ms, 1000ms) an L or T appeared on the left or right side of the screen. Participants made speeded manual inputs to indicate which letter

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appeared. Results suggest that attachment avoidance delayed response times, but only in happy trials. Further, attachment avoidance interacted with SOA, such that individuals high in avoidance made slower responses in happy trials as the SOA increased. Conversely, individuals low in avoidance made faster responses in happy trials as the SOA increased. These effects only emerged at later SOAs (>600ms). The results suggest positive faces actually capture the attention of avoidant individuals, but only in the later stages of emotional face processing. The null results for fearful faces suggest that it may be specific negative faces (e.g, angry) that interact with avoidance. The results do not confirm either the hypervigilance hypothesis or the disengagement hypothesis. Instead, the results suggest the effect of attachment avoidance on emotional face processing is emotion-specific and emerges at specific points in the time course of emotional face processing.

Attention: Reward

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4001 Pavlovian reward learning underlies value driven attentional capture

Berno Bucker[1](berno.bucker@vu.nl), Jan Theeuwes[1]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, Amsterdam, The Netherlands

Typically, if attending a target stimulus is consistently paired with obtaining high reward, then that stimulus becomes more likely to capture attention compared with an equally salient stimulus associated with low reward. Recent evidence extends this finding by showing that task-irrelevant distractors that signal high compared with low reward availability also elicit stronger capture, even when this is detrimental for task-performance and monetary payout. This suggests that the simple correlation between stimuli and reward delivery, rather than their instrumental relationship with obtaining reward, underlies value driven attentional capture. However, in previous studies, reward delivery was never response independent, as only fast and correct responses were rewarded, nor completely task-irrelevant, as the only way to discover how much reward could be earned on a trial was to attend the reward signaling distractor. In the present study we specifically addressed whether the mere correlation between stimuli and obtaining reward, completely independent of the current task and/or response, was able to elicit value driven attentional capture. During a classical (Pavlovian) conditioning phase, twenty-four participants performed a fixation task while stimuli following high and low reward feedback were presented in the periphery. In a subsequent testing phase in which no rewards were distributed, participants performed the additional singleton task while one of the distractors was sometimes presented in the previously high or low reward-value associated color. The results revealed that high compared with low reward-value associated distractors significantly slowed response times. Furthermore we showed that value driven attentional capture was strongest directly after the reward conditioning phase and decreased over time. These results provide clear evidence that value driven attentional capture occurs following a classical conditioning procedure. This confirms and strengthens the idea that Pavlovian rather than instrumental learning of stimulus-reward contingencies underlies value driven attentional capture.

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23.4002 Oculomotor properties associated with the enhanced feature representation of reward-signaling distractors

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Recent studies have shown that reward learning affects attentional and oculomotor selection. Irrelevant distractor stimuli indicating the availability of reward can capture the eyes. It is assumed that this oculomotor capture effect is due to the operation of an attentional mechanism that is feature-specific, such that the relationship between a stimulus feature and reward enhances that feature's representation on an internal priority map. The current study examined in detail the effects of enhanced feature representation due to reward association in a new continuous, fast-paced eye movement task in which participants made saccadic eye movements to follow a target around the visual field. A colored distractor signaling high, low or no monetary reward appeared either in close or far proximity from the target, at an equal distance as the target from the current gaze position. Distractors associated with high reward led to more erroneous saccades to the distractor, resulting in no reward for those trials, and smaller saccadic amplitudes to the target. Moreover, the eyes landed closer to high reward-associated distractors in close proximity to the target (30° polar angle) compared to less rewarding distractors at that location. Distractors close to the target (30°) resulted in quicker saccadic onsets with smaller saccadic amplitudes to the target, and more erroneous saccades to the distractor, compared to distractors at more distant locations (120° or 180°). Furthermore, distractors in the same hemifield as but far from the target (120°) resulted in faster saccades to the target, with fewer erroneous saccades and less curvature towards the distractor than distractors at the same physical distance from the target, but in the opposite hemifield. These results are explained in terms of oculomotor competition in which distractors associated with high reward may gain higher priority within the oculomolotor map than equally salient distractors associated with lower reward.

Acknowledgement: This research was supported by an ERC advanced grant [ERC-2012-AdG-323413] to Jan Theeuwes

23.4003 Direct and Indirect Mechanisms of Value-Driven Attentional Guidance

Jaap Munneke[1](jaap.munneke@gmail.com), Artem Belopolsky[1], Jan Theeuwes[1]; [1]Vrije Universiteit Amsterdam

Value-driven attentional capture refers to the automatic and involuntary guidance of attention to stimuli that are associated with value. Often this form of attentional selection is based on learned associations between a stimulus and a received (monetary) reward. The rationale is that associating a stimulus with a reward boosts its representation on an attentional priority map, biasing attention towards selection of this stimulus. The work presented here investigates how and to what extent value-signaling distractors capture attention when participants are provided with prior information concerning the target's location. In a series of experiments using a classic visual search paradigm, we provided the participants with a 100% valid cue concerning the target location. At the moment the target appeared at the cued location, a salient and reward-associated distractor appeared elsewhere in the display. The results show that under changing experimental conditions (such as the likelihood of obtaining reward), presenting participants with value-signaling distractors resulted in two distinct modes of value-driven capture, relying on different underlying attentional mechanisms. The first, indirect mechanism of attentional control refers to the observation that participants abandon the top-down set for target location in favor of reward-seeking behavior, leading to capture by all singleton stimuli that may represent value. The second, direct mechanism of value-driven attentional control concerns the observation that valued, but not non-valued distractors break through the focus of attention and capture attention, despite participants not engaging in reward-seeking behavior. In the current work we investigate the properties and experimental conditions leading to direct and indirect value-driven attentional guidance. Importantly, as classic saliency-driven attentional capture does not occur under focused attentional conditions, we conclude that rewarded stimuli appear to be more strongly manifested on a priority map leading to enhanced and distinctive means of attentional guidance.

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23.4004 Was that a threat? A cueing study on attentional guidance by threat signals

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Research indicates that stimuli signaling threat may capture and hold attention. However, whether threat signals have a true effect on perception and attention or if this effect results merely from arousal and response activation is still a matter of debate. 34 volunteers completed a modified spatial-emotional cueing paradigm to examine how perceptual sensitivity (d') and response times (RT) were affected by a threatening stimulus. The color of one cue was paired with a chance to receive an electric shock, the others were neutral. Two colored circles were presented as cues at each side of fixation, one of which could be associated with a shock. Following the cues, two Gabor patches were presented; one of which was tilted and served as target. The target Gabor patch could be presented at the location of the threat-associated cue (Cued) or on the opposite side (Uncued). Stimulus onset asynchrony (SOA) between cue and target was either 100ms or 1000ms. The results showed, relative to the neutral condition, an increased perceptual sensitivity (d') and faster RTs for targets appearing at the location where the threat associated cue was presented and lower d' and slower RTs for targets appearing at opposite side of the threatening cue. This indicates that, immediately after cue presentation, attention is captured by the threat-associated cue, evidenced by the higher d' for detecting targets at the cued versus the uncued locations at the short SOA. Crucially, this enhanced perceptual sensitivity remained present for the long SOA, suggesting that attention remains focused at the location of the threatening stimulus even 1000 ms after it was extinguished. RT measures followed a similar pattern. The current results show an effect of threatening stimuli on perceptual selectivity (d'), providing unequivocal evidence that threatening stimuli can modulate the efficacy of sensory processing.

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23.4005 Reward captures attention independent of the current focus of attention

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Previous studies have demonstrated that when focusing attention to a location in space, salient stimuli outside the focus of attention do not capture attention. The present study investigated whether a non-salient but reward-signaling color outside the focus of attention still has the ability to capture attention. In the current study, participants searched for a specific color among six differently colored circles. One color of the non-target circles signaled the reward magnitude (high versus low) that could be earned on that trial. An abrupt onset cue was presented before the search array at the location of target or reward signaling distractor with equal probability. Results showed that response time was slower when attention was cued at a high-reward distractor relative to a low-reward distractor, indicating delayed disengagement from the location of a distractor that signaled a high versus a low reward. Interestingly, even when the target location was cued, response times were also slowed down by a high-reward distractor. This suggests that even when the cue directs attention to the location of the target, a high reward signaling distractor has to ability to capture attention even when the distractor is non-salient. Notably, this capture effect only occurred in the second part of the experiment suggesting that participants learned the reward contingencies between color and reward payout. Furthermore, we show a response compatibility effect: when a high-reward distractor was shown — search accuracy was higher when orientation of bar inside the target matched that of a high-reward distractor — in the second half but not the first half of experiment, again demonstrating that location-specific attentional capture by the reward distractor following reward learning. We conclude that a reward signaling distractor can capture attention even when it is not salient and even when attention is focused elsewhere in the display.

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23.4006 Through the eyes, fast and slow: behaviourally relevant pupil responses on separate timescales

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The pupil offers a window into processes that reflect neuromodulatory brain state. For example, changes in pupil diameter are thought to correlate with exploitatory and exploratory behavioural states. While many studies acknowledge that arousal-based pupil responses are important in controlling behaviour, another important source of information is a signal that carries information about the value of the current behavioural state. Here, we investigated to what extent pupil responses reflect dynamics of behavioural control related to value-based learning. Thirty participants performed an implicit reversal learning experiment where we manipulated the probability of receiving reward or punishment, while recording their pupil size. Coloured cues signalled an upcoming reward or punishment with 80% validity. The contingency between colour and reward/punishment reversed unpredictably, prompting value-based learning of cue-reward contingencies in the participant, who was required to signal these reversals by keypress. Using ridge regression deconvolution, we found pupil signals that indexed reward-based learning differently on separate timescales. Perception of value contingency reversals was tracked by slow pupil signals on a timescale of minutes and correlated with behavioural responses, whereas fast trial-based pupil signals tracked instantaneous prediction errors. These data show that slow pupil responses carry functional information about value-based learning processes over and above fast trial-based pupil responses. Our results hint at the utility of slow pupil size fluctuations as a proxy for brain states relevant to behavioural control.

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23.4007 Pupil dilation indexes effort exertion during the configuration of attentional control setting

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Attentional control settings bias the visual system to prioritize task-relevant features and properties in the environment. While a great deal of research has investigated the kinds of control settings at our disposal (e.g., shape, color, oddballs, etc), little is known about how individuals choose these settings. Some researchers have speculated that we choose the settings requiring the least cognitive effort. However, before this speculation can be addressed, it is necessary to determine if the amount of effort required to establish control varies across different control settings. Here, we use pupillometry to measure preparatory effort for two types of control settings. In two experiments (total N = 28), participants performed a visual search task containing two targets: an "easy" target (a salient color singleton, e.g. red amongst blue items) or a "difficult" target (a less salient shape singleton, square amongst diamonds). On each trial, participants were instructed to make a saccade to one of the two targets, which was cued by a tone at the start of the trial. We measured pupil dilation, a well-established indicator of cognitive effort, focusing specifically on the preparatory period between the tone and the presentation of the search display (3.5 seconds). In both experiments, pupil dilation was larger during preparation for the difficult shape target than the easy color target. These results show that the amount of effort required to configure attentional control varies depending on the expected target properties. Moreover, the results provide a basis for the view that effort may play a key role in how individuals choose their attentional control settings.

23.4008 What Constitutes "Value" in Value-driven Attentional Capture

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Rewarding attention to a particular color results in a subsequent strong capture of attention by that color. However, the effect of associating a particular color with a loss is unclear. Punishing attention to a color might lead to suppression of attention to that color. Alternatively, both rewarded and punished colors might capture attention, if any stimulus associated with a large consequence, regardless of the valence, captures attention. Finally, it is possible that only rewards will drive the capture of attention. To test these possibilities we first trained participants to search for a target that could be either of two colors. One color was associated with a modest financial gain, the other was associated with a modest financial loss. In a subsequent search task, we found strong attentional capture by the rewarded color and weaker capture by the punished color. These results seem to show that both rewarded and punished features capture attention. However, during training the penalized color was always a target. Thus, its history of frequently being a target, rather than its consequence, might have been responsible for attentional capture. In a second experiment, the target could be any of three colors during training. One color was associated with gain, one with loss, and the third had no payouts. In a subsequent search task, the rewarded color showed strong capture and both the punished and no payout color had equivalent levels of weak, but significant, capture. These results suggest that being a frequent target during the training phase causes subsequent attentional capture. Associating a color with a gain further increased capture above and beyond this effect, but associating a color with a loss did not increase or decrease capture beyond the frequent target effect.

23.4009 Object-based effects (and their absence) reveal parallel mechanisms of emotional disruption of perception

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Emotional stimuli can capture attention and impair perception of subsequently presented targets, a phenomenon known as emotion-induced blindness (EIB). In contrast to spatial attention tasks (where emotional stimuli impair processing of targets away from their location), EIB occurs when targets and emotional distractors spatially overlap (Most & Wang, 2011). We examined whether EIB is spatially localized or spreads in an object-based manner. In two experiments, participants searched for targets within four simultaneous rapid streams of images, with each stream placed on the corner of an imaginary square. Two rectangles each enclosed two streams, such that any two streams could appear within the same "object" or across different objects (e.g., Egly, Driver, & Rafal, 1994). Emotional distractors appeared two items before targets, either within the same stream as the target or in a different stream. Emotional distractors impaired target perception when targets and distractors appeared within the same stream of images but not when these items appeared across different streams within the same object. Notably, emotional distractors did impair target perception when they appeared the same distance apart across different objects, consistent with object-based effects on spatial attention. These findings suggest that emotion-induced impairments in this task resulted from two

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parallel mechanisms: spatiotemporal competition that occurs only when the critical items appeared in the same location, and the diversion of spatial attention when targets and distractors appeared across different objects.

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23.4010 Can value learning modulate early visual processing?

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The current study examined the influence of expected value on early visual processing. Such early processing can be indexed by the C1, an event-related potential component elicited by the initial processing of visual stimuli and generated from V1. C1 has been assumed to mark activity moving in a feedforward manner through the sensory pathway. Previous literature thus claims that C1 is invariant to top-down influences, such as perceptual or emotional salience. However, recent evidence suggests that C1 can be modulated by such top-down influences. In these cases, stimuli used to elicit C1 are usually inherently meaningful (i.e. emotional faces) and therefore of an uncontrolled value. Thus, it is not clear whether stimulus valence, salience, or a combination of the two alters early sensory processing. This study aimed to address this question by imbuing stimuli with value varying in valence and probability of occurrence. Animal studies suggest that learned reward and loss values are encoded by distinct neuron populations in the amygdala (Paton et al., 2006) that could in turn influence V1 activity through amygdalate-cortical pathways (Amaral & Price, 1984). Thus, it is hypothesized that valence will modulate C1 regardless of probability. Participants first encountered novel faces in a choice task involving winning and losing money (Raymond & O'Brien, 2009) to acquire expected values, combining high and low probability with reward and loss outcomes. Learned faces were then presented in a perceptual discrimination task where participants judged the direction of tilt (45 degrees right or left). Contrary to our hypothesis, in a sample of 20 participants, the C1 elicited to the appearance of the face was modulated by probability regardless of valence, being smallest to high-probability faces and largest to low-probability faces. Results suggest that expected value in the form of probability can modulate early sensory processing in V1.

23.4011 Value-associated stimuli can modulate cognitive control settings.

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Although value associations are known to modulate attention even when they are irrelevant (Raymond & O'Brien, 2009; Rutherford et al., 2010), it remains unclear whether value affects spatial attention by changing cognitive control settings or by altering data-driven priority maps. To investigate we measured conflict adaptation (CA) effects in a classical color flanker task using value-associated (Exp 1) or perceptually salient (Exp 2) distractors. In Exp 1, participants learned to associate color symbols with monetary wins or no outcome in a simple choice task. Later, all participants made speeded color categorizations of a central symbol presented with same (congruent) or different (incongruent) flanking symbols, without the expectation of monetary reward on any trial. In such tasks, responses are slowed on incongruent trials (the congruency effect, CE) and CE effects are reduced when the previous trial is incongruent. This latter effect, known as conflict adaptation (CA), indexes task-specific, transient, conflict-driven modulations of attentional selection control settings. We reasoned that if irrelevant value-associations are able to modulate control settings, then distractor value-associations should determine CA. In contrast, CA should be unaffected by the perceptual salience of distractors, a feature that drives bottom-up attention. If value associations modulate attention in a bottom-up fashion, value and perceptual salience should have similar, null effects on CA. We report that positive versus no-outcome value-associated distractors significantly reduced CA effects, whereas perceptual salience (bright/dim) had no effect. The presence of value-associated stimuli in the scene appears to terminate conflict adaptation responses instantiated by a prior incongruent trial, without influencing CEs measured after congruent trials, a finding consistent with the notion that the presence of value-associated stimuli in a scene affects attentional control settings, not bottom-up priority maps.

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23.4012 Motivational salience produces hemispheric asymmetries in visual processing

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Introduction: Stimuli that reliably herald the availability of rewards or punishers can acquire motivational salience potentially enhancing their ability to disrupt appropriate allocation of attention. Currently, it remains unclear whether reward effects on visual processing and any hemispheric asymmetry thereof are specific to the positive valence of outcomes (gain vs loss) or more generally reflect motivational salience (stimuli that are highly predictive of outcomes). Method: To investigate we asked participants to learn to associate specific stimuli (faces in Experiment 1 & 2; chairs in Experiment 3) with modest monetary rewards or punishers that occurred with either a high or low probability. Then we centrally presented one of these stimuli (for 85 ms) just (100 ms) prior to a simple letter visual search task. Participants were required to detect the target by pressing the corresponding key while ignoring the value-learned stimuli. Results: Face distractors that had previously been highly predictive of outcomes (rewarding or punishing) versus those less predictive of outcomes slowed subsequent search for targets appearing in the left, but not the right, hemifield (Experiment 1). This finding supports the notion of a right-lateralized, motivational response mechanism that competes for control with non-emotional cognitive processes. The same effect was also observed when distractor stimuli were presented in profile view during the search task but frontally during learning, indicating that motivational salience operates on view-independent representations (Experiment 2); and when face stimuli were replaced with chair stimuli demonstrating that the motivationally induced laterality bias is not dependent on face processing, per se (Experiment 3). Conclusion: Taken together, our new findings reveal that highly motivational salient stimuli (compared to low) preferentially engage a right-hemisphere motivational system, regardless of valence (reward vs punishment), which can in turn impact the recruitment of attentional processes and slow subsequent responses to a neutral visual stimulus.

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23.4013 Exploring the limits of the "self-relevance" effect on performance

Gregory Wade[1](gwade2778@gmail.com), Timothy Vickery[1]; [1]University of Delaware

Merely associating a sense of self with a simple geometric shape stimulus is enough to enhance performance in a label-matching paradigm (Sui, He, & Humphreys, 2012), implying prioritized visual processing of self-relevant stimuli. For instance, labeling a square as "self" and a circle as "other" yields speeded performance when verifying square-self label matches compared with circle-other label matches. In three experiments, we sought to replicate this finding, explore whether it generalizes to other methods of assigning self-relevance, and examine the possibility relative salience of the "self" label underlies the effect. We employed the label-matching task and varied the labels across experiments. After a label-training stage, participants saw shapes and labels and responded "match" or "mismatch". Experiment 1 replicated previous results, showing speeded responses to "self" matches vs. "friend" and "other" matches. In Experiment 2, we asked whether ownership labels are sufficient to evoke this effect, as ownership has been shown to provide similar benefits to performance in memory tasks (Turk, van Bussel, Waiter, & Macrae, 2011). We labeled shapes as "mine", "his", and "theirs". Matches to "mine" were more quickly identified than matches to "his" or "theirs", implying that mere ownership is sufficient to evoke this effect. Finally, in Experiment 3 we asked whether increased salience of a non-self label could produce a similar effect. We induced one shape association with "self," another with "other," and another with a "stranger" who was described as "dangerous," as a means of enhancing the salience of this label through threat. The self-associated matches were still identified with greater speed than the even the "dangerous stranger," and there was no significant advantage of the stranger over the other condition. These findings replicate and extend the generality of the self-relevance effect and provide evidence that mere salience enhancement may be insufficient to explain these effects.

23.4014 Value associations of irrelevant visual features are neurally tracked during reward-based decision-making

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Many human decisions depend on learned associations between the sensory and motor features of choices and value. Little is known about how human learners solve the "curse of dimensionality," the ambiguity related to deciding which of numerous features of the environment to associate with rewarding or punishing outcomes. Reinforcement learning (RL) approaches to such decisions often implicitly assume that only relevant, attended feature-value associations are tracked, updated via reward prediction errors (RPEs), and employed in decisions. In this study, we examined whether humans are truly adept at ignoring irrelevant feature-value associations when they are explicitly aware of task-relevant dimensions.

Saturday AM

Using model-based fMRI, we examined neural responses during a simple reward-learning task (4-armed bandit), in which participants selected one of four options represented by colored squares on each trial. After selecting, participants received reward probabilistically, according to reward probability rates associated with each of the four colors. Reward rates were independent across colors and drifted over the course of the experiment to encourage participants to actively learn the values of each color throughout the experiment. Importantly, locations of the colored items were randomly determined on every trial and were completely unrelated to value. Consistent with prior work, model-based RPE corresponding to the color feature was strongly correlated with activity in several regions of the brain, including ventral striatum. However, we additionally estimated irrelevant location-value associations and corresponding prediction errors, which were then orthogonalized with respect to color RPE. Neural activity in several regions, including ventral striatum, was additionally strongly correlated with location RPE, implying latent value signals related to the irrelevant feature. Humans may track multiple feature-value associations in parallel, even when they are not presumed to be relevant to action. Such latent signals may serve to guide exploratory actions, or actions taken under high uncertainty.

23.4015 **Reward prediction is necessary for value-driven attentional capture** Chisato Mine[1](mine.chisato.68m@st.kyoto-u.ac.jp), Jun Saiki[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University

Many previous studies report that stimuli associated with reward capture attention (value-driven attentional capture; VDAC), regardless of task-relevant or task-irrelevant features. However, necessary conditions for the formation of the feature-reward association in VDAC remain unknown. Recent studies claim that VDAC is based on prediction-based associative reward-learning, but they did not directly examine the relationship between reward prediction and feature-reward association, because the temporal relationship among feature, response and reward was fixed. In the current study, we took advantage of the flexibility of the task-irrelevant reward learning and manipulated the temporal relationship among feature, response, and reward in reward learning to reveal necessary conditions for VDAC. For this purpose, we presented features associated with reward in a variety of locations in a flanker task to create color-reward association (training phase) and then examined VDAC in a subsequent visual search (test phase). First, features were presented in a task display, and we obtained a significant VDAC, which was the replication of the previous study. In contrast, VDAC disappeared when features and reward were simultaneously presented in the feedback display, suggesting that the direct association between feature and reward is not sufficient for VDAC. When reward was presented before response selection in the task display, we could not observe VDAC, suggesting that temporal precedence of response to reward is necessary for VDAC. We next examined temporal relationship between feature and response. When features were presented before the task display requiring response (fixation display), VDAC disappeared, suggesting that temporal separation of feature and response selection does not induce VDAC. Features presented after the response selection showed the same result, indicating that synchronization between features and response is necessary for VDAC. Taken together, features presented at the time of reward prediction, namely at response selection preceding reward, induce VDAC.

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23.4016 **Loss Aversion affects Inhibitory Processes for Reward as Indicated by Inhibition of Return** Summer Clay[1](summer.clay@cgu.edu), Alison Harris[1,2], Danielle Green[1], Catherine Reed[1,2]; [1]Claremont Graduate University, [2]Claremont McKenna College

This study investigates whether early orienting and inhibitory processes can be influenced by previous experience with reward or loss as well as individual differences for loss aversion. Targets following cues at delayed cue-target intervals (300-2000ms) produce slower RTs for targets appearing in the cue location compared to targets appearing in a new location—inhibition of return (IOR). IOR is well suited to investigate attention to reward and loss because it reflects an early orienting response to a particular spatial location followed by inhibitory processes that interfere with goal-directed action. Cues associated with high reward are found to enhance the IOR effect relative to neutral cues, suggesting greater inhibitory processes that interfere with task demands after orienting to a reward. Although it is an open question how cues associated with loss influence IOR, most individuals exhibit an aversion to loss outcomes (loss aversion), negatively affecting decisions by placing excessive emphasis on avoiding loss. Here we investigated whether loss aversion is related to potential costs of orienting to reward and loss cues. After training participants to associate specific cues with reward or loss, we then measured IOR in a covert-orienting paradigm. Next, participants completed a computerized risk assessment task designed to measure loss aversion (DOSE; Wang, Filiba & Camerer, 2013). Results indicated that reward, loss, & neutral cues all elicited an IOR effect but they did not differ in the size of the IOR effect. However, regression analyses revealed that individual differences in loss aversion scores were correlated with the difference in IOR between reward and neutral cues, but not the difference in IOR between loss and neutral cues. Specifically, the IOR for neutral cues were greater than for reward cues for individuals with greater loss aversion. Thus, loss aversion may be related to greater inhibitory processes after orienting to reward.

23.4017 **Beauty requires thought: The experience of beauty is selectively impaired by a demanding cognitive task** Aenne Brielmann[1](aenne.brielmann@nyu.edu), Denis Pelli[1,2]; [1]New York University, Department of Psychology, [2]New York University, Center for Neural Science

People readily distinguish beauty experiences from other mundane pleasures. This intuition is reflected in models of aesthetic experience and confirmed by fMRI evidence that prefrontal regions and the default mode network are selectively involved in experiencing beauty. This is consistent with Immanuel Kant's notion that "beauty requires thought" being a defining quality of the experience of beauty. Here we experimentally test Kant's hypothesis that beauty differs from "ordinary" pleasures in requiring cognitive capacity. Participants were presented with beautiful images (self-selected or experimenter-selected), ordinary pleasures (pretty image or eating candy), or neutral images for 30 s each. During stimulus exposure and a further 60 s after, participants continuously rated pleasure using a custom smartphone app (emotiontracker.com), which samples the distance between two fingers once per second and converts it to a numerical rating (1-10). At the end of each trial, we asked participants if they felt beauty (options: definitely yes, perhaps yes, perhaps no, definitely no). We manipulated cognitive capacity by requiring participants to execute an auditory 2-back task (N=20) in 50% of trials. Only for beautiful stimuli, continuous-pleasure and final-beauty ratings were much lower for trials with vs. without the 2-back task (M=7.7 vs. 5.5 maximum pleasure for self-selected images, and 7.3 vs. 5.4 for experimenter-selected, SE≈0.7). Pleasure and beauty ratings for all other stimuli were unaffected. In a smaller control experiment, we asked participants to remember a string of digits (one digit more than their digit span) in 50% of trials to selectively limit working memory capacities. This manipulation did not result in an impairment of beauty experiences. These results indicate that the process underlying a beauty experience has specific cognitive demands (not working memory), which, in combination with the experience of high pleasure, may be hallmarks of experiencing beauty.

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Eye Movements: Neural mechanisms and remapping

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4018 **Presaccadic changes in local field potential-derived receptive fields within the frontal eye field** Xiaomo Chen[1,2](xiaomo@stanford.edu), Marc Zirnsak[1,2], Tirin Moore[1,2]; [1]Department of Neurobiology, Stanford University, Stanford, CA, USA, [2]Howard Hughes Medical Institute, Stanford University School of Medicine, Stanford, CA, USA

Receptive fields (RFs) of neurons within the primate visual system have been reported to shift prior to saccadic eye movements. It has been widely assumed that these presaccadic RF shifts anticipate the actual retinal displacements caused by eye movements in order to stabilize vision. In contrast to this predictive remapping of RFs we recently demonstrated that RFs based on the spiking activity of frontal eye field (FEF) neurons of the macaque monkey converge massively toward the saccadic end point. Here, we investigate the presaccadic RFs derived from simultaneously recorded local field potentials (LFPs) within the FEF. LFPs reflect multiple neuronal processes including extracellular voltage fluctuations due to synaptic inputs and thus carry additional information over that of spiking activity. We quantified LFP-RFs in four different frequency bands, alpha (8-12 Hz), beta (16-30Hz), gamma (30-80 Hz), and high gamma (80-150 Hz). We obtained clear RFs only for the alpha and high gamma bands. Similar to the RFs derived from spiking activity, LFP-RFs in the alpha and high gamma bands were retinocentric during periods of fixation; that is, they

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remained fixed relative to the fovea across different eye positions. However, shortly before eye movements, LFP-RFs in the high gamma band shifted substantially. Similar to the spiking RFs, the global pattern of the high gamma band LFP-RF shifts consisted of a convergence toward the saccadic end point. In contrast, LFP-RFs in the alpha band showed no consistent shift before eye movements. Thus, LFP-RFs in the alpha and high gamma bands are presaccadically dissociated from one another. The convergence of LFP-RFs in the high gamma band is consistent with local processes contributing to the convergence of spiking activity based RFs.

Acknowledgement: This work was supported by National Institutes of Health grant EY014924.

23.4019 **Does the saccade-related burst in the superior colliculus convey commands related to the future location of a moving target ?** Laurent Goffart[1](laurent.goffart.int@gmail.com), Aaron Cecala[2], Neeraj Gandhi[3]; [1]INT, UMR 7289 CNRS Aix-Marseille Université, Marseille, France, [2]Department of Biology, Elizabethtown College, Elizabethtown PA, USA, [3]Department of Bioengineering, University of Pittsburgh, Pittsburgh PA, USA.

Following the suggestion that a dynamic command encoding the expected here-and-now target location feeds the oculomotor system during interceptive saccades, we tested whether this command originates in the deep superior colliculus (SC). Three monkeys generated saccades to targets which were static or moved along the preferred axis, away from (outward) or toward the fixation point (inward). Vertical and horizontal target motions were also tested. The animals had to make a saccade to the target and track it for few hundred msec. The target speed was generally 20°/sec. Extracellular activity of 57 saccade-related neurons was recorded. The movement field parameters (boundaries, preferred amplitude and maximum firing rate) were estimated after spline fitting the relation between saccade amplitude and average firing rate during the saccade-related burst. During radial target motion, the inner MF boundary shifted in the same direction as the target motion: toward larger amplitudes for outward motion, smaller amplitudes for inward motion. During vertical target motion, both lower and upper boundaries were shifted upward during upward motion whereas the upper boundary was shifted only during downward motions. During horizontal motions, the medial boundaries were not changed. A shift in the preferred amplitude was significant only for outward motion. Regardless of the motion direction, the average firing rate was consistently reduced for interceptive saccades. These results indicate that the saccade-related burst of SC neurons participates in the guidance of interceptive saccades. Its spatiotemporal pattern depends upon the target motion direction. When it is observed, the shift of MF boundary (in the same direction as the target motion) indicates that the neuron issued a command to orient gaze toward a past target location. The absence of shift in the direction opposite to the target motion argues against an encoding of future target location by SC activity for the generation of interceptive saccades.

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23.4020 **Role of the human parietal cortex in predictive remapping across eye movements: an online rTMS study.** Delphine Lévy-Bencheton[1](d.levybencheton@uq.edu.au), Marc Kamke[1], Jason Mattingley[1,2]; [1]Queensland Brain Institute, University of Queensland, St Lucia, QLD 4072, Australia, [2]School of Psychology, University of Queensland, St Lucia, QLD 4072, Australia

Each time we make an eye movement the retinal image shifts, yet we typically perceive the external world as stable. Predictive remapping mechanisms contribute to this visual stability by anticipating the future position of the eye, either by shifting visual receptive fields in direction of the saccade ("retinotopic" remapping) or by shifting attentional pointers in the direction opposite to the saccade ("spatiotopic" remapping) immediately prior to the eye movement. Here we used focal transcranial magnetic stimulation (TMS) to test for the first time the role of the human posterior parietal cortex (PPC) in retinotopic and spatiotopic predictive visual remapping. In an initial experiment (modified from Hunt & Cavanagh, 2011), 20 participants judged the orientation of a target in one of two vertically aligned locations in the left visual field. Targets flashed briefly and were followed by a mask at the same location as the target or at the other location. In separate runs participants either maintained fixation or performed a vertical saccade. We observed a reliable predictive remapping effect (both retinotopic and spatiotopic) for saccade trials only, for target-mask displays flashed in the 100 ms prior to saccade onset. To investigate the role of the human PPC in predictive remapping, we implemented a second experiment in which online, high-frequency repetitive TMS (rTMS) pulses were delivered 150 ms before saccade onset, either to the right superior parietal lobule (SPL) or the primary somatosensory cortex (S1; control). We chose the SPL as the experimental site based on its high spatial selectivity. Results from nine participants again revealed a significant predictive remapping effect, but no reliable influence of stimulation of the SPL relative to the S1 control site. Future experiments will involve more participants and stimulation of the inferior parietal sulcus, which some studies have also implicated in predictive remapping processes.

Acknowledgement: Fondation de France

23.4021 **Ipsilateral positivity as neurophysiological evidence for predictive remapping in humans** Viola Störmer[1,2](vstormer@fas.harvard.edu), Patrick Cavanagh[1,3]; [1]Laboratoire Psychologie de la Perception, Paris Descartes, [2]Psychology Department, Harvard University, [3]Psychological and Brain Sciences, Dartmouth College

Every time we move our eyes, the retinal image of the world shifts, but we nevertheless perceive the world as stable. Predictive remapping – a process in which neural activity elicited by a stimulus is transferred to its future, post-saccadic location before the execution of an eye movement – is thought to play a critical role in achieving this stability. Here, using EEG, we asked whether and at what point in time such remapping occurs during a simple saccade task. On each trial, participants fixated a black dot in the center of the screen that either turned red (as a cue to maintain fixation) or green (as a cue to execute a saccade to a pre-defined target location). 50 ms after the cue, a task-irrelevant visual stimulus (probe) was briefly flashed in the lower visual field halfway between the fixation and saccade target. We examined the event-related-potential (ERP) elicited by the probe prior to the execution of the saccade. During saccade preparation, the ERP waveforms showed an overall larger positivity over parietal-occipital cortex relative to when no saccade was prepared. However, this increase in neural activity was more pronounced over the hemisphere ipsilateral to the probe location – the hemisphere sensitive to the future retinal location of the probe. Surprisingly, this pre-saccadic ipsilateral positivity began only 50 ms after the probe (with the onset of the visual P1 component) and more than 120 ms before the execution of the saccade. These results are consistent with predictive remapping and suggest that during the preparation of an eye movement attention rapidly shifts to the post-saccadic stimulus location, thereby enhancing neural activity in the brain region responsible for the future stimulus location.

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23.4022 **A recurrent convolutional neural network model for visual feature integration in memory and across saccades** Yalda Mohsenzadeh[1,2](myalda@yorku.ca), J. Douglas Crawford[1,2,3,4]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Canadian Action and Perception Network, [3]York Neuroscience Graduate Diploma Program, [4]Departments of Psychology, Biology, and Kinesiology and Health Sciences, York University, Toronto, Ontario, Canada M3J 1P3

The stability of visual perception, despite ongoing shifts of retinal images with every saccade, raises the question of how the brain overcomes temporally and spatially separated visual inputs to provide a unified, continuous representation of the world through time. The brain could solve this challenge by retaining, updating and integrating the visual feature information across saccades. However, at this time there is no one model that accounts for this process at the computational and/or algorithmic level. Previously, feedforward convolutional neural network (CNN) models, inspired by hierarchical structure and visual processing in the ventral stream, have shown promising performance in object recognition (Bengio 2013). Here, we present a recurrent CNN to model the spatiotemporal mechanism of feature integration across saccades. Our network includes 5 layers: an input layer that receives a sequence of gaze-centered images, a recurrent layer of neurons with V1-like receptive fields (feature memory) followed by a pooled layer of the feature maps which reduces the spatial dependency of the feature information (similar to higher levels in the ventral stream), a convolutional map layer which is fully connected to an output layer that performs a categorization task. The network is trained on a memory feature integration task for categorization of integrated feature information collected at different time points. Once trained, the model showed how the feature representations are retained in the feature memory layer during a memory period and integrated with the new entering features. The next step is to incorporate internal eye movement information (intended eye displacement, eye velocity and position) in the model to see the effect of intended eye movements on updating of the feature maps.

Our preliminary results suggest that recurrent CNNs provide a promising model of human visual feature integration and may explain the spatiotemporal aspects of this phenomenon across both fixations and saccades.

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23.4023 Cerebral hemodynamics during scene viewing: Hemispheric lateralization predicts temporal gaze behavior associated with distinct modes of visual processing Mark Mills[1](mark.mills2@huskers.unl.edu), Mohammed Alwatban[2], Benjamin Hage[2], Erin Barney[2,3], Edward Truemper[2,4], Gregory Bashford[2], Michael Dodd[1]; [1]Department of Psychology, University of Nebraska-Lincoln, [2]Department of Biological Systems Engineering, University of Nebraska-Lincoln, [3]Yale Child Study Center, Yale School of Medicine, [4]Department of Pediatric Critical Care, Children's Hospital & Medical Center, Omaha, NE

Studies of eye movements during scene viewing often observe an increase in fixation duration and decrease in saccade amplitude with viewing time. This temporal gaze behavior has been taken as evidence for a functional distinction between two modes of viewing behavior associated with specialized cortical processing: a global/ambient mode (characterized by short fixations and large amplitudes) thought to reflect activity in the dorsal visual pathway and thus involved with spatial analysis, and a local/focal mode (characterized by long fixations and small amplitudes) thought to reflect activity in the ventral pathway and thus involved with object analysis. Currently, however, there is little neuroscientific evidence indicating that these viewing modes are indeed linked to processing in distinct cortical regions. Here, we used functional transcranial Doppler ultrasound (fTCD)—which measures cerebral blood flow velocity in basilar cerebral arteries—to investigate neural correlates of these viewing modes, particularly, whether these modes show hemispheric lateralization. Though not used in this manner before, fTCD may be ideal for studying this issue given its high temporal resolution. Participants viewed 40 real-world scenes for 20 seconds each. Prior to each scene, participants were cued either to search or memorize the scene. Overall, early viewing (first 3-5 seconds) was right lateralized, whereas later viewing (last 15-17 seconds) was left lateralized. This pattern interacted with task: search was right lateralized early with bilateral activation later on, whereas memory showed bilateral activation early and left lateralization later. Importantly, changes in lateralization correlated strongly with changes in fixation duration and saccade amplitude ($rs > .6$). These findings are the first demonstration of a right hemisphere bias for oculomotor behavior thought to service spatial analysis and a left hemisphere bias for oculomotor behavior thought to service object analysis.

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23.4024 Characteristics of eye-position gain field populations in AIT and LIP determined through genetic algorithm modeling of monkey data Sidney Lehky[1](sidney@salk.edu), Margaret Sereno[2], Anne Sereno[3]; [1]Computational Neurobiology Laboratory, The Salk Institute, [2]Department of Psychology, University of Oregon, [3]Department of Neurobiology and Anatomy, University of Texas Medical School-Houston

We have previously demonstrated differences in eye-position spatial maps for anterior inferotemporal cortex (AIT) in the ventral stream and lateral intraparietal cortex (LIP) in the dorsal stream, based on population decoding of gaze angle modulations of neural visual responses (i.e., eye-position gain fields)(Sereno et al., 2014). Here we explore the basis of such spatial encoding differences through modeling of gain field characteristics. We created a population of model neurons, each having a different eye-position gain field. This population was used to reconstruct eye-position visual space using multidimensional scaling. As gain field shapes have never been well established experimentally, we examined different functions, including planar, sigmoidal, elliptical, hyperbolic, and mixtures of those functions. All functions successfully recovered positions, indicating weak constraints on allowable gain field shapes. We then used a genetic algorithm to modify the characteristics of model gain field populations until the recovered spatial maps closely matched those derived from monkey neurophysiological data in AIT and LIP. The primary differences found between model AIT and LIP gain fields were that AIT gain fields were more foveally dominated. That is, gain fields in AIT operated on smaller spatial scales and smaller dispersions than in LIP. Thus we show that the geometry of eye-position visual space depends on the population characteristics of gain fields, and that differences in gain field characteristics for different cortical areas may underlie differences in the representation of space.

23.4025 Eye-position signals in the local field potentials of area V1 Steffen Klingenhoefer[1](steffen@klingenhoefer.de), Bart Krekelberg[1]; [1]Center for Molecular and Behavioral Neuroscience, Rutgers Universitiy

Stable vision in the presence of eye movements requires the combination of retinal information and eye position signals (EPS). One mechanism that could underlie this integration has been described throughout the visual system: in many neurons, the gain of visually driven activity is modulated by eye position. It is currently unclear, however, how this extra-retinal information is conveyed from motor-planning to visual areas. One theory proposes that inter-area communication is based on oscillatory activity, which leads to the hypothesis that EPS could be reflected in the spectral power of the local field potentials (LFP). We recorded neuronal activity in area V1 of the macaque using multielectrode arrays. The animals fixated a dot appearing at random positions on a CRT monitor (horizontal and vertical range: ±7.5 deg) while a dynamic noise stimulus was presented on the screen. We analyzed multi-unit activity (MUA) and the LFP power in the theta, alpha, beta, low-gamma (30-80 Hz), and high-gamma (80-200 Hz) bands as a function of eye position. Eye position strongly modulated visually driven MUA. This effect was robust across recordings sites, multiple fixations, and recording sessions. EPS were also reliably present in beta and high-gamma, but not in other frequency bands. EPS in high-gamma and the MUA were roughly aligned (i.e. high power at positions with high MUA), potentially reflecting a correlation between high-gamma and spiking acitvity. In contrast, the modulation in beta appeared to be anti-correlated with the MUA modulations (i.e. low power at positions with high MUA). Our data show that EPS are not confined to spiking activity and that additional information relevant for visual stability is available in the synchronous activity of populations of V1 neurons. We speculate that the beta band power reflects the top-down coordination of extra-retinal and retinal information in V1.

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23.4026 Eye movements towards or away from faces elicit different fMRI activity in the insula. Marie-Helene Grosbras[1](marieh@psy.gla.ac.uk), Emilie Salvia[1], Bruno Nazarian[2]; [1]Laboratoire de Neurosciences Cognitives, Aix Marseille University, [2]Institut des Neurosciences de la Timone,Aix Marseille University

It is well established that faces induce both faster orienting responses and more involuntary saccades than other stimuli. Here we used functional magnetic resonance imaging (fMRI) to investigate the interaction between eye-movements programming and the privileged processing of social stimuli at the neural level. We asked 17 healthy adults (7 females) to look towards (pro-saccades) or away (antisaccades) visual stimuli. They performed the task while either faces or cars stimuli appeared to the left or right of the center of the screen. FMRI time-series were acquired using a 3-T fMRI scanner. We processed and analyzed the data using both the general linear model and multi-voxel pattern approaches. We focused on regions of interest belonging to the extended face- perception and to the oculomotor-control brain networks. We also selected brain areas not directly involved in eye-movement control but frequently activated to a greater extent for anti- compared to pro-saccades (Jamadar et al., 2013). Both methods revealed the expected activation pattern when comparing anti- and pro-saccades, including, bilaterally, the frontal and supplementary eye-fields (FEFs and SEF), the superior parietal cortex, the precuneus, the insula and the anterior cingulate cortex. Likewise, faces induced greater activation than cars in expected brain regions including the fusiform and occipital face areas and the amygdala. We observed a significant interaction between task and stimulus class only in a region within the left insula, which showed large difference between anti- and pro-saccades for faces but not for cars. These results provide no evidence of different recruitment of the oculomotor network as a function of the social nature of the stimuli. Instead they suggest that the insula, a region known to be involved in emotion processing and cognitive control, might be a substrate of higher conflict processing linked to performing an anti-saccade away from a face.

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23.4027 Allocentric vs. Egocentric Coding of Remembered Saccade Targets in Human Cortex Ying Chen[1,2,4](liuc@yorku.ca), J. Douglas Crawford[1,2,3,4]; [1]Centre for Vision Research, York University, [2]School of Kinesiology and Health Science, York University, [3]Psychology and Biology, York University, [4]Canadian Action and Perception Network (CAPnet)

A remembered visual target can be defined in allocentric or egocentric coordinates, but the neural mechanisms for allocentric saccade coding in humans are essentially unknown. Here we employed an event-related fMRI design to investigate the brain areas involved in these two types of representation in twelve participants. A saccade target and an additional landmark were always presented for 2s, but at the beginning of each trial, a recorded voice instructed participants to remember target location relative to the landmark (Allo saccade) or ignore the landmark and remember target location (Ego saccade). During the following delay phase of 12s participants had to remember the target location in the appropriate coordinates. In a non-spatial control task (Color), participants remembered and reported target color later. At the end of the delay the landmark re-appeared at its original or a novel location for 2s, followed by a response of saccade or target color report. In the Ego task, participants were signaled to saccade toward or opposite to the target. We found that during the delay phase Ego and Allo tasks elicited higher activation in bilateral frontal eye fields, left midposterior intraparietal sulcus (mIPS) and superior parieto-occipital cortex, right amIPS and pmIPS as compared to the Color control. The Ego task produced higher activation in inferior parietal cortex as compared to the Allo task, whereas temporal and occipital cortex showed higher activation for Allo vs. Ego. Egocentric directional selectivity was observed in superior and inferior occipital cortex in the Ego task, whereas allocentric directional selectivity was observed in precuneus and mIPS in the Allo task. Our results indicate different cortical mechanisms for allocentric vs. egocentric target memory for saccade. Comparing this to our recent reaching study (Chen et al. Journal of Neuroscience 2014), the detailed mechanisms also depend on the motor effector (eye vs. hand).

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23.4028 **Oscillatory neural interactions in the alpha-gamma range predict successful eye-movements in a visual search task** Nina Thigpen[1](nthigpen@ufl.edu), Andreas Keil[1]; [1]University of Florida

During naturalistic viewing, goal-directed eye movements allow humans to foveate on locations containing potentially relevant visual information. These saccadic explorations of the visual field are thought to be guided by cortical top-down signals into visual areas, essential for successfully processing visual information. However, little is known regarding when and how these putative cortical signals inform goal-related saccadic eye-movements. To address this question, we examined fixation-locked phase synchrony from dense-array EEG while 30 participants visually searched nature scenes for a target animal. Scenes flickered at 30 Hz, to invoke a steady-state visually evoked potential (ssVEP) as a measure of primary visual cortical activity. We found differences in ssVEP phase-locking preceding fixations to targets, compared with control fixations to locations that did not contain a target. In particular, phase locking at the steady-state frequency remained high across a 400 ms window surrounding control fixations, suggesting consistent synchronous activation of visual cortex during control fixations by the flickering stimulus. However, 150 ms before fixation on a target, phase locking at the steady-state frequency was interrupted, suggesting less synchronous activity related to incoming visual information immediately preceding a successful saccadic eye movement. During this same time window preceding target fixations, phase locking, inter-site phase locking, and power in the alpha range increased relative to control fixations, suggesting increased top-down signaling before successful goal-related saccades. Broad band gamma activity increased 60 ms before successful target saccades, but sharply decreased immediately following fixations for another 60 ms. This gamma pattern was reversed for control fixations, showing a sharp decrease 60 ms before fixation, and a slight increase following fixations. Together, these results suggest that oscillatory signaling within visual cortex as well as between visual and extra-visual areas may mediate saccadic behavior during goal-directed visual search.

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23.4029 **Spatial and temporal features of the lambda response in fixation-related potentials** Anthony Ries[1](anthony.ries@us.army.mil), Jon Touryan[1], Patrick Connolly[2]; [1]U.S. Army Research Laboratory - Human Research and Engineering Directorate, [2]Teledyne Scientific Company

Combining simultaneous recordings of electroencephalography (EEG) and eye-tracking provides a powerful method to evaluate the neural mechanisms of vision by isolating fixation-related potentials (FRPs), evoked EEG activity during periods of eye fixation. This approach provides a means to evaluate visual information processing without imposing the constraint of central eye fixation commonly required in many event-related potential (ERP) studies. The earliest and most prominent brain potential following fixation onset is commonly referred to as the lambda response and reflects the afferent flow of visual information at fixation to visual cortex. The FRP-based lambda response is affected by low level visual features similar to the P1 ERP; however, when evoked by the same stimulus, the lambda response generally peaks earlier and has a larger amplitude compared to the P1 suggesting a difference in the underlying mechanisms. While many studies have evaluated the spatial and temporal properties of the P1 ERP, few studies have investigated these properties in the lambda response. Here we utilized independent component analysis (ICA) to separate the neural sources underlying the fixation-related lambda response obtained during a guided visual search task. We found that the lambda response in the FRP consists of both early and late source components with central occipital and lateral occipital topology respectively. These results suggest that the lambda potential may be generated by independent but temporally overlapping sources in visual cortex.

Eye Movements: Localization and stability

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4030 **Visual stability across saccades: Do the number and spatial location of non-targets influence target location processing?** Xiaoli Zhang[1](zhang.4734@osu.edu), Julie Golomb[1]; [1]Department of Psychology, The Ohio State University

To maintain visual stability, we use information from both retinal and extra-retinal sources (Currie et al., 2000). One component of retinal information is non-target objects, which can act as "landmarks" to influence target localization across saccades (Deubel, 2004; Deubel et al., 2010). The current study further investigates how people utilize non-target information, specifically whether more non-targets can provide more information, and which reference frame it is based on. In Experiment 1 participants made a saccade to a target object, followed by a blank screen, and judged whether or not the target stayed at the same location after the blank. We varied the number of non-targets present (0, 1, or 2), and whether they appeared in the same locations relative to the target across saccades ("relative" condition), or the same absolute spatial locations ("absolute" condition). Compared to when there were zero non-targets, we found a benefit on response accuracy for the relative condition with two non-targets, but not for any other conditions. Participants also had an overall stronger bias to report that the target was at the same location when non-targets were present. In Experiment 2 participants directly reported the remembered target location with a mouse click. In general, non-targets improved participants' performance in terms of both smaller response error and variance, but performance was equally good in relative and absolute conditions, as well as in one and two non-target conditions. Additionally, subjects' responses were biased toward both the original fixation location (opposite direction of saccade) and the location of the non-target(s), and these two sources of bias seemed to counteract each other when in the opposite directions. Taken together, both experiments showed effects of non-targets on target localization across saccades, but non-target number and spatial location seemed to contribute differently in the two tasks.

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23.4031 **Mislocalizations in saccadic and mask-induced suppression of displacement** Sabine Born[1](sabine.born@unige.ch); [1]Faculté de Psychologie et des Sciences de l'Education, Université de Genève, Switzerland

'Saccadic suppression of displacement' (e.g., Deubel, Schneider, & Bridgeman, 1996) denotes a difficulty in discriminating small 'jumps' (displacements) of a visual target when these jumps occur during a saccadic eye movement. The effect is supposed to reflect some aspect of spatial updating across saccades. More specifically, it is assumed to result from the necessity to compare pre- to post-saccadic coordinates. Recently, we have reported a similar difficulty in a condition without saccades, when the jump was obscured by a full-screen pattern mask (Zimmermann, Born, Fink, & Cavanagh, 2014). We suggested that, rather than spatial updating, saccadic suppression of displacement may also primarily reflect the saccade's masking effect on the visual input stream. We further hypothesized that masking may cause an underestimation in the perceived size of the target jump. Here, instead of using the classic binary response mode ('leftward or rightward jump?'), participants were asked to precisely indicate the target's perceived starting position by mouse click. In accordance with a smaller perceived jump, the initial target position was systematically mislocalized towards the target's final position in both mask and saccade conditions. The systematic bias increased with larger target jumps, reminiscent of the phenomenon of saccadic or mask-induced compression of space (Ross, Morrone, &

Burr, 1997; Zimmermann et al., 2014). In contrast, in a control condition without saccades or masks, small displacement sizes (< 1 deg) were slightly overestimated. Finally, when a short blank interval between the disappearance of the target at its initial position and its reappearance at the displaced position was introduced, no systematic mislocalizations occurred, suggesting that the effect depends on a critical time window for integration of spatial positions, again reminiscent of the saccadic compression window. These results are further evidence for a common mechanism underlying saccadic and mask-induced mislocalization and suppression effects.

23.4032 **Monocular visual localization during eye movements** Stefan Dowiasch[1](stefan.dowiasch@physik.uni-marburg.de), Frank Bremmer[1]; [1]Department of Neurophysics, Philipps-University Marburg, Marburg, Germany

Eye movements induce visual spatial mislocalization of briefly flashed stimuli. The neural basis of this perceptual phenomenon is as yet unknown: physiological, behavioral and theoretical studies have suggested various neural mechanisms, from displacement of visual receptive fields during eye movements to erroneously decoded eye position. Here we utilized the mislocalization of briefly presented stimuli during different types of monocular eye movements (i.e. fixation, saccades and smooth pursuit eye-movements) to induce a perceptual localization shift into the area of the blind spot, a region of the retina that is physiologically blind due to the absence of photoreceptors. Our study confirmed previous findings on binocular mislocalization for monocular vision and showed that mislocalization induced by different types of eye movements is capable to shift the perceived location of targets to a position a subject should be blind for. Furthermore, the area for which each subject perceived the least amount of targets, forming a perceptual blind spot, shifted for each form of eye movement in a characteristic manner. The distinctive shapes of the perceptual blind spots for each subject were basically preserved during eye movements as compared to fixation. In all cases, perceived location of stimuli presented close to the blind spot were shifted towards its center, inducing a resetting of the typically observed increase of mislocalization for larger retinal eccentricities. Our findings imply a combination of two independent neural signals as the neural basis of stimulus localization: a visual map and an eye-position signal. Both signals might be combined at a rather late processing stage, in which visual space is already fully represented. This hypothesis predicts, at a neuronal level, visual receptive fields at identical retinal locations across eye movements and agrees well with previous studies suggesting the source of perceptual mislocalization during eye movements by an erroneous internal representation of eye-position.

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23.4033 **Does memory affect perisaccadic compression?** Maria Matziridi[1](Maria.Matziridi@psychol.uni-giessen.de), Karl Gegenfurtner[2]; [1]Faculty of Psychology, Philipps University Marburg, Germany, [2]Department of Psychology, Justus-Liebig University Giessen, Germany

Briefly presented stimuli around the time of a saccade tend to be mislocalized towards the endpoint of the saccade, a phenomenon called perisaccadic compression. It has been suggested that compression might be affected by landmarks other than the saccade target. We examined whether this would also hold for items represented in visual memory. We asked five participants to localize a green bar briefly presented around the time of a 7 degree rightward saccade. One second before the initiation of the saccade, an object was presented for 100 ms in one of three possible locations on the screen to the right of the fixation cross at 4, 6, and 8 degrees. In half of the sessions, participants were instructed to memorize the location of the object and indicate it at the end of each trial after indicating the location of the green bar. In the other half of the sessions, participants were instructed to indicate only the location of the green bar. Other than the difference in the instruction, participants saw the same stimuli in both parts of the experiment. In a control experiment, the orange was not presented at all. There was no effect of memory on the overall amount of compression or on its time course. A small (0.5 deg) shift in the center of compression away from the memory item was observed in the condition when the memory item was in the far position relative to the saccade target. Our results show that items in visual memory have no or only a very limited effect on perisaccadic compression.

23.4034 **Pre-saccadic remapping is an attentional process** Martin Szinte[1](martin.szinte@gmail.com), Dragan Rangelov[1], Donatas Jonikaitis[2], Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany., [2]Department of Neurobiology and Howard Hughes Medical Institute, Stanford University School of Medicine, Stanford, USA.

Each eye movement shifts the projections of the visual scene on the retina. It has been proposed that the receptive fields of neurons in oculomotor areas are remapped pre-saccadically to account for these eye-movement induced retinal displacements. Remapping of the whole visual scene however seems prohibitively complex as it would require numerous connections as well as an efficient transfer of activity between a large number of neurons before each saccade. Selection by visual attention may simplify these processes by predicting what the world would look like after the saccade only for a subset of attended objects. Here we report clear evidence that pre-saccadic remapping is an attentional process. In our study, we cued a spatial location by presenting an attention capturing salient object at different times before a saccade and determined detailed spatio-temporal maps of attentional allocation across the visual field. We observed that when the cue appeared shortly before saccade onset, spatial attention was allocated both to the cued location and to the saccade goal. In contrast, when the cue appeared sufficiently early before saccade onset, attentional resources that were initially drawn to the cued location were now reallocated to its remapped location (i.e. the retinal location it will occupy after the saccade). Since selection by visual attention is time-consuming, our findings suggest that remapping is an attentional process, limited to visual objects that have been given sufficient time to be attended.

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23.4035 **Perisaccadic remapping of visual information is predictive, attention-based, and spatially precise** Melchi Michel[1,2](melchi.michel@rutgers.edu), James Wilmott[1]; [1]Department of Psychology, School of Arts and Sciences, Rutgers University, [2]Rutgers Center for Cognitive Science (RuCCS), Rutgers University

A growing number of physiological and psychophysical studies have reported that visual information is spatially remapped in a brief interval preceding the onset of an intended saccade. Researchers have interpreted these results as evidence of predictive remapping: an updating of visual or attentional receptive fields in anticipation of a saccade. Recently, this interpretation has been challenged by an alternative hypothesis that any apparent remapping is not predictive, but rather an epiphenomenon of saccadic target selection (Zirnsak & Moore, 2014). Last year (Michel & Parikh, 2015), we presented results from a reverse correlation study of transsaccadic perceptual discrimination designed to gather and evaluate evidence of remapping under either hypothesis. Observers were asked to report the average luminance polarity of a small, flickering Gaussian blob displayed peripherally for 500ms, whose luminance in each 10ms frame was selected randomly. We found that when irrelevant flickering blob stimuli were added to the display, laterally flanking the target at a distance equal to the magnitude of the instructed saccade, observers' reports were influenced by the luminance of the stimulus in a location corresponding to the prospective retinal location of the discrimination target (in a direction opposite the saccadic target). Importantly, information from this location only influenced the decision in the 100ms preceding the onset of the saccade, consistent with perisaccadic remapping. In the current study we modified the task by adding additional, intermediate, flankers to better characterize the spatial characteristics of the remapping. We found that the remapping is spatially precise. Of the 4 flankers we presented, only the one consistent with the prospective retinal location of the discrimination target influenced the discrimination in the perisaccadic interval. This result is consistent with remapping that is predictive and attention-based (e.g., Cavanagh, Hunt, Afraz, & Rolfs, 2010). We argue that it is inconsistent with remapping due to saccadic target selection.

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23.4036 **Maintaining a stable world across eye movements: Object and location information can operate independently in corrective saccades.** Martijn Schut[1](m.j.schut@uu.nl), Jasper Fabius[1], Stefan Van der Stigchel[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, The Netherlands

Saccade execution is quite inaccurate, leading to a frequent undershoot of saccades. To compensate for this inaccuracy, the intended target is stored in working memory prior to the saccade. Object and spatial information are encoded in separate working memory storages. When the eyes do not land accurately, a visual search task is performed and guided by working memory content. Research suggests a corrective saccade could then be initiated towards the intended target, contributing to our perceived stability of the world. However, it is still unknown if both spatial and object information can independently facilitate corrective saccades. In our current study we dissociated the contribution of spatial and object information by inducing inhibition of return (IOR) in a gaze correction paradigm (Hollingworth, Richard, & Luck, 2008). In Experiment 1 we found increased latency for saccades to previously fixated objects. Corrective saccades to previously fixated objects at updated locations showed lower latency. In Experiment 2 we controlled for acquisition of surface features during initial fixation. Corrective saccades were facilitated to an IOR associated object even when surface feature information was unavailable during initial fixation. In Experiment 3 we disentangled location and object specific information by adding a second rotation to the stimulus array. We only found IOR in corrective saccades when location and object information were congruent to previously fixated object and location. We found facilitated corrective saccades when an previously fixated object was either moved to a novel location or when an IOR associated location was occupied by another object. Together these findings imply that corrective saccades are facilitated by previously fixated object and location information and that both types of information can contribute separately in correcting for gaze errors. Congruence in object and location specific information may re-engage attentional effects from a past visual scene, thus contributing to a stable world.

Eye Movements: Cognition

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4037 Modeling the Task Control of Gaze

Dana Ballard[1](dana@cs.utexas.edu), Leif Johnson[1], Mary Hayhoe[2]; [1]Department of Computer Science, University of Texas at Austin, [2]Department of Psychology, University of Texas at Austin

In natural behavior, visual information is actively sampled from the environment by a sequence of gaze changes. The timing and choice of gaze targets, and the accompanying attentional shifts, are intimately linked with ongoing behavior. Nonetheless, modeling of the deployment of these fixations has been very difficult because they depend on characterizing the underlying task structure. Recently, advances in eye tracking during natural vision, together with the development of probabilistic modeling techniques, have provided insight into how the cognitive agenda might be included in the specification of fixations. These techniques take advantage of the decomposition of complex behaviors into modular components. A particular subset of these models casts the role of fixation as that of providing task-relevant information that is rewarding to the agent, with fixation being selected on the basis of expected reward and uncertainty about environmental state. In a previous study gaze behavior in a driving task where subjects followed a lead car and maintained a given speed, we showed that specific values for each subtasks's reward and uncertainty allowed the distribution of a human subject's fixation intervals of each of the subtasks to be approximated very closely as measured by KL divergence between human and model probability distributions (average value 0.79). The current work extends this result by showing that the ratio of measured uncertainties in the human data closely approximate the ratio used in the model, implying that both the uncertainty and reward parameters used by the model are commensurate with those used by the human subject.

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23.4039 Neural Correlates and Saccadic Eye Movements Involved during Letter Naming Speed Tasks

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Naming speed (NS) tasks measure how quickly and accurately subjects can name sets of highly familiar stimuli (e.g., letters) randomly presented in a visual array. NS performance has been shown to be a precursor and concurrent correlate of accurate and efficient reading. However, it is still not known what cognitive processes underlie this relationship. We used functional magnetic resonance imaging (fMRI) to investigate the neural substrates and cognitive processes underlying performance during letter and object naming speed (NS) tasks. We used three methods to evaluate task performance: (a) changing stimulus composition to emphasize phonological and/or visual aspects; (b) decomposing NS times into pause and articulation components; and (c) analyzing eye movements and brain activation involved in a NS task. 19 healthy young adults (ages 21 - 26 yrs) were recruited. We employed a block design consisting of a letter NS task and three variants with increased phonological and/or visual similarity (Compton, 2003), and an object NS task with a variant in which the object names rhymed with one another, while subjects' eye movements and articulations were recorded. We examined how these manipulations influenced performance and whether they resulted in differences in neural activation. Results indicated that letter NS manipulations were associated with specific patterns of performance which were influenced by visual rather than phonological similarity. When the task was both visually and phonologically similar, participants had significantly longer naming times and fixation durations, and made more frequent saccades and regressions. The letter NS tasks activated regions that are involved in the reading network, including the temporoparietal areas, inferior frontal cortex, and the ventral visual stream, as well as in the saccadic eye movement network. Activation in the temporoparietal areas of the reading network varied by task indicating differential neural processes that are associated with each letter NS task.

23.4040 Failure in inhibiting eye movements in a cued probe-matching task

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We often shfit our gaze to an interesting stimulus; but it is important to inhibit eye movemens in some environments (e.g. no-look pass in basket ball). Here, we tested our ability in this goal-directed inhibition when participants had to report peripheral target stimulus in the cued location. We measured eye movements while participants were performing a cued-matching task. An array of eight letters composed of four characters was briefly presented and participants reported the item presented at the cued location under the instruction of maintaining strict fixatoin at the cetrally presented fixation cross. Stimulus onset asynchrony (SOA) determining the cue to target array interval was chosen from six values (-400, -200, 0, 200, 400 and 800 ms), resulting in pre-cue conditions (-400 and -200 ms SOA), a simultaneous cue condition (0 ms SOA) and post-cue conditions (200, 400 and 800 ms SOA). Results show that participants shifted their gaze toward the cued direction even though the target array was absent at the onset of eye movements. The eye movements have the following characteristics. First, eye movements were shifted to the cued location, but their amplitudes on average were considerably smaller than the actual location of the target item. Second, eye movements occurred approximately 300 ms from the cue onset in the simultaneous and post-cue conditions, but 200 ms from the memory array onset in the pre-cue conditions. Third, the magnitude of eye movements was on average similar under different cue conditions. However, in the post-cue conditions, the magnitude was larger in the incorrect trials than in the correct trials while their onsets were similar. These results demonstrate that eye movements often escape our inhibitory control.

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23.4041 Fixation stability during the performance of a high-precision manipulation task

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Numerous studies have shown a stereotypical hand-eye temporal coordination pattern during the performance of reaching and grasping movements. Typically the eyes fixate on the object prior to the initiation of hand movement, which provides high acuity information about the object, such as its shape, orientation or material properties. The information extracted while fixating on the object is important for programming grip aperture and grasp forces, contributing to efficient execution of manipulation tasks. However, every attempt at steady fixation consists of small involuntary eye movements: microsaccades, ocular drift, and tremor. Fixation stability, quantified using bivariate contour elliptical area (BCEA), is reduced during monocular compared to binocular viewing during a visual fixation task (Gonzalez et al 2012). Since grasping is also disrupted during monocular viewing, in this study we examined fixation stability during the performance of a high-precision manual task. Fifteen visually-normal adults grasped a small bead, and placed it on a vertical needle while their eye movements were recorded binocularly. BCEA was calculated for fixations on the bead and the needle, in each viewing condition. In contrast to the hypothesis, fixation stability was significantly better with the dominant eye when fixating on the bead during monocular viewing while there was no difference between the binocular and non-dominant eye viewing conditions. A correlation analysis between BCEA and the performance of grasping and placement tasks showed that better fixation stability was associated with a significantly shorter duration of the grasping and placement actions during monocular viewing. These results indicate that fixation stability contributes to the performance of high-precision manipulation tasks when binocular vision is removed.

23.4042 **Oculomotor Measures of Learning Attentional Templates**

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Visual selection is served by attentional templates, which are memory representations of task-relevant (target) information. Recent studies using cued visual search tasks in combination with electrophysiological markers of visual working memory (VWM) suggest that observers initially keep the template in VWM but then rapidly offload it to long-term memory (LTM) when the target repeats. The present study uses eye-tracking to investigate if the oculomotor system can also provide useful markers of attentional learning. Participants first received a cue as to which target to look for in a subsequent search display, which was presented after an approximately one second delay. Search displays consisted of Landolt Cs with gaps in eight possible orientations. The same target was then repeated for another six trials, as was the cue indicating the target identity. After seven trials in total, observers received a new cue indicating the new target, which was then repeated again. Crucially, the cues were presented lateralized and were so small that observers had to make an eye movement to discern it. If learning leads to a shift from VWM to LTM, then it becomes unnecessary to look at the cue, predicting a reduction in cue-directed saccades. However, this is not what happened: Although a speeding of search RTs indicated learning with target repetition, saccade rates to the cue hardly decreased. Instead, repetition of the cue led to a decrease in fixation duration on the cue. Making processing of the cue more costly (using symbolic cues) or even useless (using completely uninformative cues) led at best to a moderate decrease in saccadic orienting to the cue. The results indicate that fixation duration is a more reliable marker of cue-based attentional learning than saccadic orienting is. Instead, saccadic orienting may be used to retrieve learned memories, using the cue as an "external pointer".

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23.4043 **Associative learning in peripheral perception of shape**

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The cortical representation of a visual object differs radically across saccades. Several studies claim that the visual system adapts the peripheral percept to better match the foveal view (Bompas & O'Regan, 2006; Valsecchi & Gegenfurtner, 2015; Herwig & Schneider, 2014). Recently Herwig et al. (2015) found that the perception of shape demonstrates this saccade-contingent learning effect. Here, we ask whether this learning actually requires saccades and propose that a more general learning process is involved. We replicated Herwig et al.'s (2015) study and introduced a fixation condition. In an acquisition phase participants were exposed to objects whose shape systematically changed during a saccade, or during a displacement from the periphery to the fovea (without a saccade). Following acquisition, objects were perceived as less (more) curved if they previously changed from more circular (triangular) in the periphery to more triangular (circular) in the fovea. This pattern was seen for both conditions, with and without saccades. We then tested whether a variable delay (0, 250, 500 or 1000 ms) between the presentations of the peripheral and foveal objects would affect their association – hypothetically weakening it at longer delays. Again, we found that shape judgements depended on the changes experienced during acquisition and that they were similar in both the saccade and fixation conditions. Surprisingly, they were not affected by the delay between the two object presentations. These results indicate that even a delay of 1000 ms between the presentation of peripheral and foveal objects supports learning of the correspondence between these two retinal stimulations. These results suggest that a general associative learning process, independent of saccade execution, contributes to the peripheral perception of shape – and our impression of object uniformity across saccades.

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23.4044 **Predicting the Number You Will Think of Based on Your Eye Scan Pattern**

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Can we predict thought from eye scan patterns? We addressed this issue in the context of predicting choice in a number generation paradigm. The goal of Experiment 1 was to see if information contained in eye scan patterns helps predict the number participants would choose later. Participants (n=37) were shown a number line (with no numbers) for 300 ms followed by a blank screen and an oral prompt: "Think of number 1, 2, or 3 and say it out loud" (5, 21, 11 responded '1', '2', '3' respectively). Fixation location and saccade magnitude after the number line presentation, after the prompt, and just before the participant responded were extracted as features for a pattern classification algorithm. A principal components analysis selected three principal components, which represented about 90% of variance in the data, that were fed into the pattern classifier (random forest) resulting in 89% accuracy (leave-one-out cross-validation) in predicting participant responses, providing evidence of a subconscious influence of eye position/movements on subsequent number generation. The goal of experiment 2 was to show if driving the eye to a different location prior to presentation had an influence. In the control condition, participants (n=21) could think of 1 or 2. A strong bias was observed in favor of 1 (16/21). In the experimental condition, new participants (n=21) faced the same binary choice as those on the control but with one key difference: on the right side of the screen, a video of a seagull flying was displayed on the screen for 350 ms; the rest of the experiment was identical to control. There was a drastic, significant change in preference compared with control: a strong bias in favor of '2' (18/21). This suggests a causal influence of eye position/movements on subsequent number generation.

23.4045 **Can you see me? Eye fixations of the face are modulated by perception of a bidirectional social interaction**

Michael Kleiman[1](mjkleiman@gmail.com), Elan Barenholtz[1]; [1]Florida Atlantic University

Previous studies of eye fixations during language encoding have found that fixation attention allocated to either the eyes or the mouth depends on factors such as task demands and language familiarity. These studies have only considered cases in which the observer is viewing a prerecorded video, where the observer's fixation behavior cannot be viewed by their interlocutor, in contrast with real-world social interactions in which the interlocutor can observe said fixation behavior. Under such real-world conditions, the fixation behavior of the observer may also serve to communicate with the interlocutor, for example by signalling interest via gaze locking or communicating emotional expression. This absence of bidirectional communication in previous studies may lead to altered fixation behavior. To test this, we compared eye fixation patterns for 'Live' vs. 'Prerecorded' viewing of a talking face. In order to achieve maximal similarity across conditions, both used the same two recorded video sequences of a presented article, each with instructional segments and story segments. One video (Live condition) used deception to encourage observers to believe that they were interacting with a live person who was able to see and hear them through online remote video communication, and in the other (Prerecorded condition) observers were informed that they were watching a previously recorded video. We found that eye fixations were more heavily focused on the eyes in the Live condition than in the Prerecorded condition. Additionally, we found that the type of information (instructional vs story) resulted in differing patterns of facial eye fixations, with instructions resulting in more fixations of the eyes than the story portion. The findings demonstrate that the belief that an interlocutor can observe gaze direction modulates the allocation of attention towards facial regions during language encoding, and suggest that previous studies may lack ecological validity.

23.4046 **Attentional synchrony during narrative film viewing: Turning off the "tyranny of film" through a task manipulation at odds with narrative comprehension**

John Hutson[1](jphutson@k-state.edu), Thomas Hinkel[1], Clarissa Boberg[1], Mauricio Caldera[1], Cheyenne Menzies[1], Kaydee Tran[1], Joseph Magliano[2], Timothy Smith[3], Lester Loschky[1]; [1]Kansas State University, [2]Northern Illinois University, [3]Birkbeck, University of London

During reading, eye-movements are closely related to comprehension, but the opposite has been shown in film viewing. Recent studies have shown that the high attentional synchrony found during film viewing may leave little room for comprehension based eye-movement differences. We therefore tested the following two competing hypotheses: 1) The Cognitive Task Hypothesis: high-level task processes guide eye-movements, versus 2) The Tyranny of Film Hypothesis: movies produce strong attentional synchrony regardless of higher-level processes. Previous experiments testing similar hypotheses showed that manipulations of viewer comprehension showed little effect on eye-movements, thus strongly supporting the tyranny of film hypothesis. To test whether the tyranny of film could be "turned-off," thus supporting the Cognitive Task hypothesis, participants were explicitly told their task was to draw a detailed map from memory of all locations depicted in a video, the 3-minute opening shot from "Touch

of Evil" (Welles, 1958). In this clip a bomb is placed in a car at the beginning, and is shown until the bomb in the car is just about to explode. Map task viewers' eye-movements were compared to participants who watched the same clip while free viewing. To measure viewers' comprehension at the end of the clip, we asked them what would happen next, which showed the large expected task difference in terms of mentioning the bomb. The free-view group was much more likely to mention the bomb, indicating they were following the narrative, and are thus referred to as the Comprehension condition. For the eye-movement measures, compared to the Comprehension condition, the Map Task produced significantly longer saccades, different fixation patterns, and less looks at the car with the bomb. Thus, while comprehension differences produce only small effects in film viewers' eye-movements, a task implicitly at odds with comprehending the film narrative counteracts the tyranny of film.

Perceptual Organization: Neural mechanisms

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4047 **A song of scenes & sentences: signatures of shared cortical resources between visual perception and language revealed by representational similarity analysis** Peer Herholz[1](herholz@staff.uni-marburg.de), Verena Schuster[1], Melissa Vo[2], Andreas Jansen[1]; [1]Laboratory for Multimodal Neuroimaging (LMN), Department of Psychiatry, University of Marburg, [2]Scene Grammar Lab, Goethe University Frankfurt

Previous imaging studies, investigating the domain specificity of cortical networks, have indicated some common principles of processing across different cognitive functions and therefore shared cortical resources, e.g. the processing of hierarchical structures ("syntax") or contextual meaning ("semantics"). Whereas the majority of research focused on language and music, recent studies also emphasized comparable principles in visual perception. However, little is known about the degree of possibly shared cortical resources between vision and language. To overcome this existing gap, we created a paradigm consisting of two modalities, visual (natural scenes) and auditory (sentences) stimuli, equally divided into consistent, semantically inconsistent, and syntactically inconsistent. Twenty participants either viewed images or listened to sentences while BOLD-responses were recorded. We assessed cortical activation patterns for semantic and syntactic language processing, applying the general linear model in each participant's native space, thus creating participant and semantic/syntax specific functional ROIs (pfROIs). Subsequently we conducted a representational similarity analysis (RSA) within those pfROIs including activation patterns from all conditions and modalities to investigate the relationship between activation patterns of language and visual perception more closely. Both language conditions activated the expected left-lateralized networks, compromising IFG, STS/MTG and IPL (semantic) and IFG, as well as STS/STG (syntax). RSA in all pfROIs revealed distinguishable patterns between modalities. Focusing on the patterns more closely we found highest similarities across modalities for both, semantic and syntactic processing in their respective pfROIs. In particular, the semantic pfROIs showed highest similarity between the activation patterns for semantic processing of language and vision, whereas syntactic processing revealed most similar activation patterns in the syntactic pfROIs. These results underline a specific and distinct processing for semantic and syntax, additionally giving a first insight on common principles between vision and language, as the resulting activation patterns for either semantic or syntax processing were most similar across modalities.

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23.4048 **Ensemble perception of size in chimpanzees and humans.** Tomoko Imura[1](imuratomoko@gmail.com), Fumito Kawakami[2], Nobu Shirai[3], Masaki Tomonaga[2]; [1]Niigata University of International and Information Studies, [2]Primate Research Institute, Kyoto University, [3]Niigata University

Comparative cognitive studies have shown that the ability of perceptual grouping in humans is superior to other species (e.g., Imura and Tomonaga, 2013). However, it is still unknown whether other species represent overall statistical properties when multiple similar objects appeared simultaneously (e.g., Chong & Treisman, 2003). The present study examined the ability to compute the mean size of sets of objects. We presented chimpanzees and humans with two arrays of 12 white circles against a gray background. One of the arrays had larger mean size of circles than the other. There were three experimental conditions; single condition (only one circle was appeared in an array), homogeneous condition (circles in an array had the same size), and heterogeneous condition (circles in an array had different size). Chimpanzees and humans were required to touch the array containing larger circles. The results showed that the performance under the homogeneous and the heterogeneous conditions were higher than that under the single condition in chimpanzees and humans. In addition, both humans and chimpanzees showed no significant difference in accuracy between the homogeneous and the heterogeneous conditions. Thus, the results were almost consistent with those reported by Chong and Treisman (2003). Additional experiments ruled out the possibility that chimpanzees used local visual properties, such as luminance of visual patterns and/or the largest or the smallest circle in the arrays, to choose the array had larger mean size. The results of this study suggest that chimpanzees can represent overall statistical properties of multiple visual objects.

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23.4049 **Imagery receptive fields** Jesse Breedlove[1](breedlov@musc.edu), Ghislain St-Yves[1], Cheryl Olman[2], Thomas Naselaris[1]; [1]Department of Neurosciences, Medical University of South Carolina, [2]Department of Psychology, University of Minnesota

Recent neuroimaging studies have shown that brain activity generated during mental imagery in early visual cortex encodes the same low-level visual features that are encoded during perception. This finding was obtained by fitting voxel-wise encoding models to activity generated during perception, and then using those models to predict activity generated during imagery. The success of this analysis lends plausibility to the concept of an imagery receptive field (iRF): a region of the mental visual field in which imagined stimuli evokes real brain activity. To determine if iRFs are in fact instantiated in early visual cortex, we measured whole-brain BOLD activity as participants viewed and then imagined previously memorized objects at 8 distinct locations in the visual field. We then fitted voxel-wise encoding models to the activity generated during mental imagery. These models assigned an iRF size and center to each voxel. In general, the iRF sizes obtained by this analysis were larger and more scattered than their visual counterparts. To visualize the iRFs, their centers were mapped to visual field space and colored according to the amount of activity generated during perception of each of the 8 object locations. This visualization revealed that iRFs do indeed characterize the relationship between activity and imagined stimulus location, and that the relationship is largely conserved during perception. To validate the iRFs we performed a classic population-vector style analysis of population activity. Specifically, we performed a vector summation of the iRF centers scaled by brain activity. For both perception and imagery, the length of the resulting population vectors were significantly greater than could be obtained if the receptive field centers were unable to predict measured brain activity ($p < 0.01$, randomization test). These preliminary results demonstrate the feasibility and potential power of iRF for exploring the functional role of imagery in vision.

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23.4050 **Neural correlates of configural superiority and emergent features: an ERP study** Thiago Costa[1,2](e.thiagocosta@gmail.com), Kimberley Orsten-Hooge[3], Gabriel Rêgo[1], James Pomerantz[4], Paulo Boggio[1]; [1]Social and Cognitive Neuroscience Laboratory - Mackenzie Presbyterian University, Brazil, [2]Instituto de Psicologia – Universidade de São Paulo, Brazil, [3]Department of Psychology – University of Arizona, USA, [4]Department of Psychology – Rice University, USA

We examined the neural correlates of both the configural superiority effect (CSE) and specific individual emergent features (EFs) via a 128-channel EEG system. We tested 20 healthy subjects in an odd quadrant task where subjects searched for the one unique stimulus among three homogeneous distractors. Experiment 1 used three display types: Base displays composed of negative and positive diagonal lines; CSE displays composed of those same four diagonal lines combined with homogeneous L-contexts to form arrows and triangles containing multiple EFs such as closure and intersection differences known to create large CSEs; and Configural Inferiority Effect (CIE) displays again composed of the Base display lines combined with homogeneous contexts to form stimuli lacking EF (configural) differences. Significant differences between displays were found for all ERP components (as early as the P100), as revealed by larger amplitudes at lateral occipital sites and faster responses at frontal sites for CSE displays, suggesting a unique time course of neural processing for CSE displays. In a second experiment, we used odd quadrant displays with dot stimuli producing the EFs of Proximity, Linearity, Orientation, and Surroundedness (Pomerantz & Portillo, 2011) to further investigate whether these EFs exhibit distinct neural correlates. Significant differences among EFs were found for the EEG but not for the behavioral data. EFs did not lead to significant differences before the N170 ERP component. Orientation, Linearity, and Proximity significantly differed from each other at the N170 and at later time windows (300-500ms after stimulus onset). In general, Orientation responses evoked larger ERPs and some hemispherical asymmetries. Our results are in accordance with the previous literature regarding the nature of the CSE as well as the hierarchical structure of EFs (Pomerantz et al., 1977, Pomerantz and Portillo, 2011) and are the first demonstrations of the possible neural correlates of these effects using EEG.

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23.4051 **Cortical Areas Involved in the Coding of Relative-Motion and Relative-Disparity Cues** Yiran Duan[1](yirand@gmail.com), Peter Kohler[1], Anthony Norcia[1]; [1]Department of Psychology, Stanford University

Segmentation cues, such as differences in binocular disparity (relative disparity) and motion direction (relative motion), make important contributions to perceiving figure-ground segmentation. These two cues strongly covary at object boundaries, so visual areas that carry signals defined by both could potentially combine them to support a more robust representation of objects and surfaces. Here we use functional MRI to directly compare activations to the two cues in a within-subject design (n=9). We compared responses to the appearance and disappearance of a central 2° disc-shaped region. In the relative motion paradigm, blocks comprising uniform field motion alternated with blocks in which the central-disk motion was in antiphase with that of the background (segmentation by relative motion). In the second paradigm, red-blue anaglyphic dynamic random-dot stereograms were presented such that in one block, the central disk-region popped out from background when the center and surround motion disparities changed in anti-phase (segmentation by relative disparity). In the other block, the disparities changed uniformly across the whole field. We compared activations within 16 topographically organized regions-of-interest (ROIs) defined for each participant using a recently developed probabilistic atlas (Wang et al., 2014). We found that TO1 (corresponding to MT; Amano et al., 2009) responded to the relative motion cue exclusively. A comparison between V3A and V3B revealed that the latter responded strongly to both the relative motion and disparity cues, while V3A responded to neither cue. Besides V3B, several other ROIs including LO1, LO2 and IPS0 had equally strong responses to both motion and disparity cues. By contrast, visual field maps on the ventral surface (VO1 and VO2) were not activated by either cue. These results suggest that the joint encoding of relative motion and relative disparity cues may involve multiple, dorsally located topographically organized visual areas.

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23.4052 **Identifying cortical areas involved in perceptual decisions about symmetry** Peter Kohler[1](pjkohler@stanford.edu), Anthony Norcia[1]; [1]Psychology, Stanford University

Wallpaper groups are a class of maximally regular textures that consist of 17 sub-groups, each defined by a unique combination of four fundamental symmetries: mirror reflection, translation, rotation and glide reflection (Liu et al 2010). We have previously shown that four of these groups, all containing rotation symmetry, elicit responses in human visual cortex that increase linearly with the maximal order of rotation symmetry present in each group. We observed this effect in three areas of the ventral visual processing stream (V4, VO1 and LOC), as well as in area V3, but not in earlier visual areas (Kohler et al., J. Neurosci., in press). These results raise an important question: Which parts of this network of areas drive behavioral responses about symmetry? Here we address this question using a perceptual decision-making task and EEG source imaging of response-locked activity. Participants discriminated images containing rotation symmetry from control images containing only translation symmetry in a speeded two-alternative forced choice task. We localized EEG responses evoked during the task to functionally defined regions-of-interest in visual cortex. We found responses that differed for fast and slow reaction times in visual areas including LOC, V4, and potentially V3. V1 showed no evidence of this effect. This indicates that the timing of behavioral responses to symmetry in wallpaper groups is driven by activity in visual areas at least as early as V4. There is converging evidence that perceptual decision-making is at least partly driven by areas that are also associated with the encoding of input stimuli (Ales et al 2013, Cottereau et al 2014, Dmochowski & Norcia 2015). Our data are well aligned with these findings, and emphasize the contribution of early visual areas to multiple visual tasks, including the detection of visual symmetry.

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23.4053 **Orientation discrimination depends on co-activation of on- and off-centre visual channels** Alan Freeman[1](Alan.Freeman@sydney.edu.au), Gloria Luo-Li[1], David Alais[2]; [1]Sydney Medical School, The University of Sydney, [2]School of Psychology, The University of Sydney

INTRODUCTION. It is becoming increasingly clear that visual responses to light increments and decrements are not symmetrical: both behavioural and neural data show that responses to darks are stronger and faster than to lights. Our aim was to see whether this asymmetry influences orientation discrimination. METHODS. We separated Gabor patches into light bars and dark bars, and presented the two components asynchronously. Bars were tilted 2° left or right of vertical but the tilt on any one trial was the same for light and dark bars. Adult human subjects indicated whether the tilt was leftward or rightward, and the probability of a correct response was plotted against stimulus contrast. RESULTS. Contrast sensitivity, obtained from the psychometric functions, was maximal when the light bars preceded the dark bars by 13 ms (1 video frame). Sensitivity fell sharply with stimulus onset asynchronies differing from this value. In particular, sensitivity was suboptimal when light and dark bars were presented simultaneously. CONCLUSION. It is commonly accepted that orientation-selective neurons receive convergent input from on- and off-centre subcortical inputs. Given the recent finding (Jin et al., J. Neuroscience, 31, 17471) that off-centre inputs usually precede on-centre inputs, our results are consistent with the idea that orientation-selective neurons require coincident on- and off-input for maximal sensitivity.

23.4054 **Mapping out the Representational Space for Decisions using EEG Delta Oscillations** Atsushi Kikumoto[1](kikumoto@uoregon.edu), Theo Schäfer[2], Tessafay Sameshima[1], Dagger Anderson[1], William McGuirk[1], Ulrich Mayr[1]; [1]University of Oregon, [2]Philipps-Universität Marburg

Perceptual decision making requires the process of translating sensory evidence into a representational space that identifies action-relevant categories (i.e., decision evidence). Although the neural dynamics of evidence integration have been investigated, it remains unclear how the representational space is organized for sensory versus decision evidence, how it adapts to task demands, and how it contributes to individual differences in quality of decision making. We decoded the representation of evidence during multi-sampling categorization tasks (Wyart, et al., 2012, Neuron) using multivariate pattern classification analysis of scalp-recorded EEG. Participants made binary judgments about the degree to which a series of Gabor patterns with variable orientations (sensory evidence) was on average closer in terms of their angular distance (decision evidence) to one of two sets of axes (e.g., cardinal or diagonal axes). We found that the representational space of sensory evidence showed a graded property, suggesting feature-selective responses. In contrast, representations of decision evidence showed the combined effect of a graded coding of the strength of the evidence, and a non-graded, binary coding along category boundaries. The neural measure of decision evidence predicted––to a much larger degree than the measure of sensory evidence––trial-by-trial errors as well as individuals' performance. Over the course of evidence presentation, the category distinction in the decision evidence representation was strengthened. Furthermore, when decision rules shifted from block to block, the category boundary was flexibly adjusted, indicating that the translation from sensory to decision evidence is under top-down control. These findings demonstrate a novel approach towards characterizing the organization of decision-relevant representations.

23.4055 **Perceptual Organization in Parkinson's disease: The Role of the Basal ganglia in Shape-Based Object Recognition and Emotion Perception** Padmapriya Muralidharan[1](padma92@vt.edu), Anthony Cate[1,2]; [1]Department of Psychology, Virginia Polytechnic Institute and State University, [2]Center for Human-Computer Interaction, Virginia Polytechnic Institute and State University

INTRODUCTION: The basal ganglia (BG) modulate inferior temporal activity, which may account for visual hallucinations of complex items (bodies, faces) experienced by many patients with BG disorders like Parkinson's Disease (PD; Middleton & Strick, 1996). This project tested the hypothesis that BG mediate perceptual organization (PO), specifically with respect to two themes we identified from a review of PD clinical reports: part-whole integration and facial expression perception. METHODS: This

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project consisted of two studies with complementary methods: a re-analysis of an fMRI study on part-whole perception that showed BG activation in healthy participants (N=17), and a behavioral study with PD patients and age-matched controls (age > 40; both N=5). fMRI stimuli were 2D shapes composed of different local contour features. Three distinct block design conditions presented different subsets of these shapes, which permitted analysis of part-whole contingencies. Behavioral tests were the L-POST (Torfs et al., 2014), which assesses a range of PO processes; and a custom emotional expression recognition test based on the Karolinska Directed Emotional Faces. RESULTS: Bilateral caudate nucleus body activation was tightly correlated ($t > 4.8$, FDR $p < 0.05$) with the degree to which local features appeared in multiple distinct whole shapes within a set. No BG regions were activated above fixation baseline by shape viewing in general. The PD patients in our sample were not significantly impaired relative to controls on the behavioral tasks. However, controls performed below the L-POST normative range on the embedded figures subtest. CONCLUSION: We identified a specific BG in the caudate body that was activated by a specific part-whole contingency and not by visual stimulation. This activation may reflect the increased salience of local parts produced when the same part appears in multiple whole shapes. This in turn may relate to embedded figure perception, which was impaired in our participants.

23.4056 **LSD alters eyes-closed functional connectivity within the early visual cortex in a retinotopic fashion** Leor Roseman[1](leor.roseman13@imperial.ac.uk), Martin Sereno[2], Robert Leech[1], Mendel Kaelen[1], Csaba Orban[1], John McGonigle[1], Amanda Feilding[3], David Nutt[1], Robin Carhart-Harris[1]; [1]Department of Medicine, Imperial College London, [2]BUCNI, Birkbeck University, [3]The Beckley Foundation

ABSTRACT Introduction: The question of how spatially-organized activity in the visual cortex behaves during eyes-closed, LSD-induced, visual psychedelic imagery has never been empirically addressed, although it has been proposed that under psychedelics the brain may function “as if” there is visual input when there is none (de Araujo, et al., 2012). We suspected that eyes-closed psychedelic imagery might involve transient local retinotopic activation, of the sort typically associated with visual stimulation. To test this, it was hypothesised that under LSD areas of the visual cortex with congruent retinotopic representations would show stronger RSFC compared to areas with incongruent retinotopic representations. Method: In this work, resting-state functional connectivity (RSFC) data was collected from 10 healthy subjects under the influence of LSD and, separately, placebo. Using a retinotopic localiser performed during a non-drug baseline condition, non-adjacent patches of V1 and V3 that represent the vertical or the horizontal meridians of the visual field were identified. Subsequently, RSFC between V1 and V3 was measured with respect to these a priori identified patches for both LSD and placebo. Results: Consistent with our prior hypothesis, the difference between RSFC of patches with congruent retinotopic specificity (horizontal-horizontal and vertical-vertical) and those with incongruent specificity (horizontal-vertical and vertical-horizontal) was significantly greater under LSD than placebo ($p=0.0017$, 1-tail, Cohen’s $d=1.6$). Conclusion: The result suggest that activity within the visual cortex under LSD becomes more dependent on its intrinsic retinotopic organization. This result indicates that under LSD, in the eyes-closed resting-state condition, the early visual system behaves as if it were seeing spatially localized visual inputs. Reference de Araujo, D.B., Ribeiro, S., Cecchi, G.A., Carvalho, F.M., Sanchez, T.A., Pinto, J.P., De Martinis, B.S., Crippa, J.A., Hallak, J.E., Santos, A.C. (2012) Seeing with the eyes shut: Neural basis of enhanced imagery following ayahuasca ingestion. Human brain mapping, 33:2550-2560.

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23.4057 **Organization of orientation selectivity in V1 of the nine-banded armadillo (Dasypus novemcinctus)** Benjamin Scholl[1](scholl.ben@gmail.com), Nicholas Priebe[2], Jeffrey Padberg[3]; [1]Max Planck Florida Institute for Neuroscience, [2]Center for Learning and Memory, Center for Perceptual Systems, Department of Neuroscience, University of Texas at Austin, [3]Department of Biology, University of Central Arkansas

Orientation selectivity has been described in neurons of V1 for all mammals investigated thus far. Despite the ubiquitous expression of V1 orientation selectivity, distinctions exist across mammalian clades with regard to its functional organization. In primates orientation selectivity is organized in discrete columns across V1 whereas in rodents and lagomorphs orientation selectivity lacks clear organization or is organized in clusters. The overwhelming majority of studies of V1 to date have been conducted in carnivorans, primates, and rodents, which are members of superclades Laurasiatheria and Euarchontoglires. To gain a more complete understanding of the evolutionary trajectory of the functional organization of the neocortex, members of other mammalian superclades must be examined. Xenarthra, represented by anteaters, sloths, and armadillos, is considered to be either the basal eutherian superclade (placental mammals) or a sister superclade to Afrotheria, with an origin approximately 100 million years ago. Here we used the nine-banded armadillo (Dasypus novemcinctus) to determine whether the columnar organization that is the hallmark of visual cortex in carnivorans and primates is apparent in xenarthrans. After initially mapping the retinotopy of armadillo V1 using multi-unit recordings, we recorded single unit responses to drifting grating of different orientations. Drifting gratings (0.02-0.04 cycles per degree) at the preferred orientations activate armadillo V1 neurons strongly, and neurons are significantly orientation tuned using the OSI metric (mean OSI = 0.15 +/- 0.16). To determine whether a functional organization for orientation selectivity exists, we compared the orientation preference of neurons recorded along our electrode penetrations. We did not find evidence for a functional organization for orientation selectivity in armadillos, as the difference between neurons’ orientation preferences was not related to the distance between recordings. These results suggest that the functional organization found in carnivorans and primates emerged through convergent evolution and does not reflect a shared mammalian functional organization.

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23.4058 **Illusory and Real Contour Processing: Findings from a Joint Event-related Potential – Functional MRI Analysis** Jonathan Wynn[1,2](jkwynn@ucla.edu), Amy Jimenez[1], William Horan[1,2], Junghee Lee[2], Gabrielle Pascual[2], Eric Reavis[2], Michael Green[2,1]; [1]Veterans Affairs Greater Los Angeles Healthcare System, [2]Semel Institute for Neuroscience and Human Behavior, University of California, Los Angeles

Neural mechanisms involved in processing real and illusory contours (e.g., Kanizsa figures) have previously been assessed with event-related potentials (ERPs) or functional MRI (fMRI). In our study, we combined information from EEG and fMRI to assess the underlying neural structures and chronometry associated with illusory and real contour processing. ERP and fMRI data were collected from 20 participants who viewed images containing illusory contours (IC), no contours (NC), or real contours (RC). The P100, N100 and P200 ERP responses to the images were analyzed in the EEG data. The N100 was significantly larger for IC vs. NC, while the P200 was significantly larger for RC vs. IC. In the MRI data, the main contrasts examined were IC vs. NC and IC vs. RC. All stimuli activated the lateral occipital complex (LOC), with no significant differences in activation. We combined information from both modalities using a joint independent component analysis (jICA) approach (Calhoun et al., 2006), comparing IC vs. NC stimuli, and IC vs. RC stimuli. For jICA, the N100 was associated with activity in a frontal-parietal network, including the middle frontal gyrus, superior parietal lobule, and LOC, with significantly more activity for IC vs. RC and NC stimuli. The P200 was linked to activity in the occipital cortex, primarily LOC, and was significantly larger for RC vs. IC and NC stimuli. The ICA-based joint spatiotemporal analysis revealed findings that were not discernible in either the ERP and fMRI results alone. The analysis suggests that illusory contour processing involves both frontal and parietal regions to a greater extent than real contour processing. By contrast, the analysis suggests that processing of real contours is more closely associated with occipital activity. These results are consistent with a “frame-and-fill” mechanism.

23.4059 **Template fitting to automatically derive V1-V3 retinotopy from inter-areal functional correlations** Andrew Bock[1](bock.andrew@gmail.com), Noah Benson[2], Marcelo Mattar[3], Geoffrey Aguirre[1]; [1]Department of Neurology, University of Pennsylvania, [2]Department of Psychology, New York University, [3]Department of Psychology, University of Pennsylvania

Retinotopic mapping traditionally presents simple visual stimuli (e.g. drifting bars, expanding rings), yet the technique is limited by the stimulus and the need for fixation. It is also inefficient, as voxel-by-voxel measurements of retinotopy do not leverage the strong prior of spatial organization in early visual areas. Here, we describe a method to simultaneously discover the retinotopic organization of visual areas V1-V3 without the need for fixation or traditional retinotopic mapping techniques. Three subjects underwent MRI at 7T. From the MPRAGE anatomical image of each hemisphere for each subject, a set of possible retinotopic templates for V1-V3 were generated. Each template varied in the precise location and orientation on the cortical surface, occupying a point in a three dimensional template parameter space (Benson et al. 2012; 2014). During BOLD fMRI scanning (1.5mm3, TR=2s) subjects freely-viewed 30 minutes of Pixar animated shorts (12.5° width visual angle). The time series data from each occipital vertex was used to create a cross-correlation matrix, with structure in this matrix induced by the shared visual stimulation experienced by vertices that represent similar points in visual space. Each possible retinotopic template also predicts a particular pattern of correlation across vertices. For each hemisphere, a search was conducted incorporating cortical receptive field sizes and the retinotopic templates to find the predicted correlation matrix that best fit the time series data. For all 6 hemispheres, the best fitting template was very similar to the retinotopic organization measured by traditional techniques. These results demonstrate that retinotopy can be obtained for areas V1-V3 using complex and continuous 'naturalistic' visual input, without the need for fixation, and allows for retinotopic mapping in subjects with difficultly fixating on a central target due to behavioral or ophthalmologic limitations.

23.4060 **Rejecting a perceptual hypothesis: Evoked potentials of perceptual completion and completion breaking** Matt Oxner[1](moxn128@aucklanduni.ac.nz), Stuart McGill[1], William Hayward[1], Paul Corballis[1]; [1]School of Psychology, University of Auckland

The appearance of illusory contours, as in the Kanizsa square, is thought to result from the perceptual inference of unseen occluding objects. While the neural correlates of the formation of illusory contours have been previously described, little is known about how new sensory evidence affects the associated perceptual inference. Here, we investigated event-related potentials (ERPs) evoked by illusory contours (a perceptual hypothesis) and subsequent motion which broke figure completion (evidence disconfirming the hypothesis). Eleven participants performed an unrelated probe detection task as we recorded electrical scalp activity using EEG; simultaneously, task-irrelevant arrays of four inducers ("pacmen") were presented which either formed a Kanizsa square or were perceptually incomplete. After one second of static presentation, inducers rotated dynamically so as to either support the percept of an occluding surface (hypothesis-supporting) or break the Kanizsa illusion (hypothesis-violating). Consistent with previously observed correlates of perceptual completion (e.g. Murray, Foxe, Javitt, & Foxe, 2004), the initial static presentation of completed Kanizsa squares evoked more negativity than incomplete inducer arrays in lateral occipital electrodes, in the N1 component and between 250 and 350 ms following static presentation. In the dynamic phase, enhanced positivity was noted in frontoparietal electrodes between 200 and 300 ms after motion onset for hypothesis-violating (i.e. completion-breaking) inducer motion when compared to completion-supporting motion. Critically, this effect was attenuated for perceptually incomplete control arrays. The frontoparietal scalp distribution of the violation-related modulation implies the involvement of high-level regions of the cortical visual hierarchy in the interpretation of a visual scene, with feedback therefrom driving the associated perception of illusory contours.

Multisensory Processing: Clinical

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4061 **Multisensory Enhancements with Unconscious Visual Stimuli in Posterior Cortical Atrophy** Ayla Barutchu[1](ayla.barutchu@psy.ox.ac.uk), Glyn Humphreys[1]; [1]Department of Experimental Psychology, University of Oxford

Multisensory signals can enhance information processing even with task irrelevant sensory signals and cues, suggesting that some aspects of multisensory processing may be automatic. Nevertheless, the role of awareness in multisensory processing remains elusive. We aimed to investigate multisensory processing in a patient with posterior cortical atrophy (65 years at the time of testing) who presented with severe visuospatial problems and strong aspects of simultanagnosia. We also tested 12 age-matched controls using a simple audiovisual detection task. Participants responded to auditory, visual and semantically congruent and incongruent audiovisual presentations of a 'bird' and a 'dog' with varying stimulus onset asynchronies (SOAs): ranging between -300 - 300 ms. Healthy control participants responded to all signals with very high accuracy (M accuracy > 95% for all stimuli). Surprisingly, they also showed large multisensory gains for both congruent and incongruent presentations of multisensory stimuli in close temporal proximity (i.e., SOA < 200 ms). The participant with PCA failed to respond to over 95% of visual only stimuli, and the hit rate when visual signals were present did not differ from the false alarm rate when signals were absent. Nevertheless he showed multisensory enhancements in reaction time when the auditory signal was presented first, and, overall, the reliability of motor responses also improved. The data show for the first time that awareness of visual signals is not a pre-requisite for multisensory enhancements. Patients with severe visual perceptual deficits can benefit from multisensory signals even at an unconscious level. This finding broadens the possibility of new multisensory-based intervention strategies for patients with severe perceptual deficits.

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23.4062 **Modality independent recruitment in the occipital lobe: A meta-analysis of early-blind and sighted fMRI and PET studies.** William Brixius[1,2](wjbrixius@gmail.com), Jessica Green[1,2]; [1]Institute for Mind and Brain, University of South Carolina, [2]Department of Psychology, University of South Carolina

Occipital cortex is classically considered vision-specific, with the exception that visual loss results in recruitment for non-visual tasks. However, crossmodal and multisensory processing research suggests that occipital activity is modulated by non-visual inputs, particularly when vision is degraded or temporarily limited. One possibility is that occipital regions receive inputs from multiple sensory modalities (vision, audition, touch), with vision the most informative for tasks recruiting occipital areas, therefore dominating occipital processing. Thus, when visual input is removed, non-visual occipital responses can be "unmasked". To investigate occipital recruitment by non-visual stimuli, we conducted activation likelihood estimation meta-analyses on fMRI and PET studies reporting early-blind and sighted participant neural activations for auditory and tactile tasks. Analysis of early-blind>sighted contrasts revealed an early-blind activation network comprising bilateral cuneus, lingual and inferior occipital gyri, and right-lateralized middle occipital and inferior temporal gyri. These results support the notion that similar occipital areas are recruited in the early-blind for non-visual spatial information as those recruited in sighted participants during visual tasks. In a second analysis, we examined auditory and haptic task>rest and task>task coordinates reported for early-blind participants and sighted participants with temporarily restricted vision. The conjunction of early-blind and sighted participant activity revealed common activation in bilateral cuneus and inferior parietal lobule, right lingual, postcentral, and superior/inferior temporal gyri, and left insula, middle temporal, and medial frontal gyri. The consistent inclusion of lingual gyrus and cuneus across modalities suggests that auditory and somatosensory modalities can recruit occipital cortex for non-visual processing, even in sighted individuals. The similarity of the recruited areas in sighted individuals and those whose vision was lost early in life further suggests that occipital cortex may be organized for specific functions (e.g., spatial localization, object identification, motion processing) in all modalities, but that these tasks are most easily accomplished using visual input.

23.4063 **Multisensory Redundancy Gains for Audiovisual Stimuli after Early Visual Deprivation** Adelaide de Heering[1](adelaide.deheering@uclouvain.be), Giulia Dormal[2], Terri Lewis[3,4], Daphne Maurer[3,4], Olivier Collignon[5]; [1]UNESCOG, Université Libre de Bruxelles, Bruxelles, Belgium, [2]Biological Psychology and Neuropsychology, Universität Hamburg, Hamburg, Germany, [3]Department of Psychology, Neuroscience & Behaviour, Hamilton, Canada, [4]The Hospital for Sick Children, Toronto, Canada, [5]Centro Interdipartimentale Mente/Cervello (CIMeC), Università di Trento, Mattarello, Italy

Multisensory integration (MSI) is essential to coordinate complex behaviours. It has a protracted period of development (Gori et al., 2010) and is influenced by early experience (Wallace et al., 2007). For instance, animal studies suggest that a short and transient period of visual deprivation early in life permanently alters the brain mechanisms of MSI (Wallace et al., 2004). In humans, the behavioural consequences of early visual deprivation on the development of MSI remain unclear. Specifically, for « simple » audiovisual stimuli, MSI is sometimes preserved (Putzar et al., 2012) and sometimes altered (Putzar et al., 2007). For « complex » audiovisual stimuli such as the McGurk effect, MSI is often altered (Putzar et al., 2010). To clarify this issue, we measured audiovisual redundancy gains in a group of 13 adult patients who had been treated for bilateral congenital cataracts during early infancy (end of deprivation: 9-238 days) and a group of gender- and age-matched controls. The first task involved simple stimuli (beeps and flashes) designed to target the superior colliculus (Girard et al., 2013; Wallace et al., 2004). The second task was composed of complex face/voice emotional expressions thought to target high-level cortical regions (Collignon et al., 2008). The cataract-reversal group showed a redundancy gain of the same magnitude as controls: for both tasks, detection in the multisensory condition exceeded the best unisensory condition and did so by

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the same amount as in controls. The results imply that the absence of visual input during the first months of life does not prevent the development of audiovisual cross-modal interactions manifested as redundancy gains.

23.4064 Frequency-tuned auditory motion responses within hMT+ in early blind individuals

Elizabeth Huber[1](ehuber@uw.edu), Fang Jiang[2], Ione Fine[1]; [1]Department of Psychology, University of Washington, Seattle, WA, [2]Department of Psychology, University of Nevada, Reno, NV

Introduction: Several fMRI studies have demonstrated novel responses to auditory motion in hMT+ in early blind and sight recovery subjects. Recently, Watkins et al. (2013) noted weak frequency-tuned responses within hMT+ in anophthalmic individuals hearing stationary tones. Here, we show that the auditory motion responses produced in hMT+ as a result of early blindness are also frequency selective. Methods: Tonotopic mapping was carried out in 4 early blind and age-matched sighted controls using (1) stationary pure tones and (2) a moving auditory stimulus. The moving stimulus consisted of band pass noise bursts centered at one of 7 frequencies (125-3952 Hz) in a semi-random order, with motion simulated using ITD and Doppler. Each event lasted 2s and contained a pair of 1s bursts travelling at 30 m/sec from left to right, or vice versa, along the fronto-parallel plane. Subjects performed a one-back task on the center frequency. The frequency tuning of each voxel was then estimated as a Gaussian in log frequency space using population receptive field modeling (Thomas et al., 2014). Results and Conclusions: In primary auditory cortex, stationary pure tones and moving band-pass stimuli produced highly similar tonotopic maps for both early blind and sighted subjects. Within hMT+ in sighted subjects, neither the moving nor the stationary stimulus elicited frequency-tuned responses. In contrast, within hMT+ in early blind subjects, robust frequency tuning was evident with the moving stimulus; these responses were much weaker for the stationary stimulus. Thus, after early blindness, hMT+ exhibits selectivity for auditory frequency as well as direction of motion. This is analogous to the selectivity for spatial frequency and motion direction normally seen in hMT+ and may serve to enhance the ability of early blind individuals to segregate individual auditory objects within complex auditory scenes.

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23.4065 Adapted use of audiovisual information for person and object recognition in people with one eye

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The ability to identify people is essential for everyday social interactions. It can be quickly achieved based on identity information from cues such as a person's face and the sound of their voice. We asked how people with one eye, who have reduced visual input and altered auditory (Hoover, Harris & Steeves, 2012, EBR) and audiovisual processing (Moro & Steeves, 2011, EBR), will use face and voice information for person identity recognition. We investigated person (face and voice) and object (car and horn) identity recognition using an old/new paradigm. Participants were presented with pairs of faces and voices (Experiment 1), as well as, cars and horns (Experiment 2) and were asked to remember the identity pairings. Recognition of visual, auditory and audiovisual (congruent and incongruent pairings) identities in people with one eye were similar to binocular and monocular viewing controls. However, unlike controls, the addition of auditory information facilitated bimodal identity recognition for people with one eye but not controls. The addition of visual information facilitated bimodal object identity recognition but not bimodal person recognition for people with one eye, while controls show the opposite pattern. Binocular viewing controls had better sensitivity for congruent compared to incongruent audiovisual pairings indicating that they based their person and object recognition according to their dominant modality (vision), whereas people with one eye did not. These results indicate that people with one eye may have adaptive strategies, such as not relying on vision as the dominant modality in order to perform similarly to controls. Changes in underlying neural structure and connectivity may provide the compensatory mechanism for the loss of binocular visual input.

23.4066 The audiovisual temporal binding window in unilateral amblyopia: monocular and binocular effects

Michael Richards[1,2,3,4](michael.richards@mail.utoronto.ca), Herbert Goltz[1,4], Agnes Wong[1,2,4]; [1]Department of Ophthalmology & Vision Sciences, University of Toronto, Toronto, Canada, [2]Department of Ophthalmology & Vision Sciences, The Hospital for Sick Children, Toronto, Canada, [3]Institute of Medical Science, University of Toronto, Toronto, Canada, [4]Program in Neurosciences & Mental Health, The Hospital for Sick Children, Toronto, Canada

Introduction: Constructing an internal representation of the external world involves continuous integration of multiple sensory streams. In the audiovisual realm, sensory signals with high temporal correspondence are likely to be bound into a single perceptual event. The range of signal onset asynchrony (SOA) over which paired audiovisual stimuli are perceived as simultaneous is known as the audiovisual temporal binding window, and normally narrows from childhood to adolescence. Amblyopia is a developmental visual impairment that is increasingly recognized to involve deficits in audiovisual integration, even when viewing with the fellow eye. We characterized the audiovisual temporal binding window in adults with unilateral amblyopia to further our understanding of the impact of developmental sensory disturbance on multisensory perception. Methods: All experiments were conducted in a dark acoustic chamber. Visual stimuli were presented on an LED screen, and auditory stimuli were presented via stereo speakers. Each trial consisted of a brief flash (32 ms) accompanied by an auditory click of equal duration. The SOA between the flash and click varied from 0 ms to 450 ms for both visual-lead and auditory-lead conditions. Participants with unilateral amblyopia ($n = 12$) and normal control participants ($n = 22$) judged simultaneity in a 2-AFC task under binocular conditions. A subset was tested under monocular conditions. Results: Adults with unilateral amblyopia had a broadened audiovisual temporal binding window compared to control participants in both the visual-lead and auditory-lead conditions ($p < 0.01$). There was no effect of viewing eye among participants tested monocularly. Conclusions: The temporal binding window is broadened in adults with unilateral amblyopia under both binocular and monocular viewing conditions. The associated audiovisual temporal binding window is similar to that observed in normal children, suggesting that unilateral amblyopia disrupts the normal process of developmental tuning.

23.4067 Top-Down Knowledge Improves Recognition of Noisy Haptic Patterns in the Blind and Sighted

Amy Kalia[1](akalia@mit.edu), Linday Yazzolino[2], Lotfi Merabet[2], Pawan Sinha[1]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA, [2]Massachusetts Eye and Ear Infirmary, Harvard Medical School, Boston, MA

Top-down influences allow the visual system to perceive globally meaningful structures in spatial patterns that may be locally noisy. This has been demonstrated in classic effects such as the Dalmation dog picture and black-and-white thresholded Mooney images (Gregory, 1970; Mooney, 1957). Yet, in the case of vision, global spatial organization is facilitated by a large field of view that allows the image to be viewed in a few, or even just a single, glance. Is global perceptual organization a necessary pre-requisite for the manifestation of top-down facilitation? The haptic modality provides an opportunity to address this question given the sequential nature of haptic exploration and the resulting dominance of local shape processing (Berger and Hatwell, 1993; Lakatos and Marks, 1999; Lederman and Klatzky, 2009; Panday, Tiest and Kappers, 2012; Puspitawati, Jebrane and Vinter, 2013). Here, we examined whether 2D haptic image recognition is enhanced by top-down knowledge, and whether prior visual experience modulates this enhancement. Congenitally blind and sighted participants felt shapes embedded in noise on a refreshable Braille display. The images became progressively less noisy until participants recognized the shape. Overall, blind individuals recognized the shapes in higher levels of noise compared to sighted individuals ($p = 0.011$), suggesting that modality-specific experience enhances recognition of noisy tactile patterns. When the shapes were presented for a second time, both blind ($p = 0.019$) and sighted ($p = 0.003$) participants recognized them in higher levels of noise compared to novel shapes, demonstrating an effect of top-down knowledge on haptic spatial perception that is independent of visual experience. We conclude that the influence of top-down knowledge on the interpretation of ambiguous spatial patterns generalizes across sensory modalities.

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Multisensory Processing: Vision and hearing, cognition and neural correlates

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4068 A novel paradigm to examine how multisensory integration, perceptual learning, and statistical learning jointly contribute to perceptual performance

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It is well established that our visual perceptions are jointly determined by visual input, expectations of the world, and informative inputs to other sensory modalities. Numerous studies examine different aspects of this equation. For example, studies of multisensory integration (MI), perceptual learning (PL), and statistical learning (SL) detail, respectively, interactions between modalities that lead to improved processing of multisensory objects, improvements in perceptual processing after repeated exposure to certain stimuli, and learning of relationships between stimuli after repeated exposure. Researchers typically design paradigms that investigate one of these phenomena independently and discuss the results in terms of mechanisms for that phenomenon alone. However, it is unclear the extent to which cognitive processes responsible for these three types of learning share common mechanisms and how their interactions impact perception. To investigate this, we designed a novel paradigm through which to understand how MI, PL, and SL jointly influence perception. Across multiple days, participants performed a discrimination task at threshold contrast on audio-visual stimuli that appeared in different locations according to controlled spatio-temporal statistics. Behavioral data show that all three manipulated factors (MI, PL, SL) can be dissociated within the same paradigm. We will also present preliminary electroencephalography data addressing interactions between these extra-retinal factors. Paradigms such as this have important implications for a wide variety of fields as the results can help elucidate underlying mechanisms driving different types of learning and also demonstrate where these different types of learning may intersect.

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23.4069 Task irrelevant visual input reduces accuracy of echolocation in a size discrimination task

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Background: Echolocation is the ability to perceive the environment by making sonar emissions and listening to returning echoes. For people, it has been suggested that echolocation may not only draw on auditory, but also 'visual' processing (Arnott, Thaler, Milne, Kish, & Goodale, 2013; Thaler, Arnott, & Goodale, 2011; Thaler, Wilson, & Gee, 2014). Here we used an interference paradigm to further explore the interaction between vision and echolocation. Method: Blindfolded sighted echo-naive participants used mouth-click based echolocation to discriminate sizes of objects. Participants wore black-out goggles fitted with LEDs. The goggles blacked out vision of the environment at all times, but LEDs when switched on also provided task-irrelevant visual input. In a control condition, blindfolded sighted and blind participants performed the same echolocation task, whilst also wearing electrode patches, which when switched on provided task-irrelevant tactile stimulation (i.e. Transcutaneous Electrical Nerve Stimulation). Results: Participants' echolocation accuracy scores were significantly reduced in conditions where luminance input had been provided, as compared to conditions where it had not been provided. This drop in performance was not observed in the control condition that had used task-irrelevant tactile stimulation. Discussion: The results suggest that visual but not tactile sensory input 'interferes' with echolocation, suggesting that vision and echolocation may interact at an early sensory stage in the human brain

23.4070 Auditory Pitch Influences Time-to-Contact Judgments for Visual Stimuli

Carly King[1](carlypking@gmail.com), Thomas Qiao[1], Steven Prime[1]; [1]Neurocognition & Psychophysics Lab, Department of Psychology, University of Saskatchewan

Auditory pitch has been shown to interact with spatial and velocity estimates. Upward and fast movements are associated with higher-frequency and ascending pitches and vice versa for lower-frequency and descending pitches. The extent to which pitch affects visual motion perception remains unclear. We investigated whether ascending and descending pitch glides of a continuous tone influence perceived speed or spatial position of a visual motion stimulus in a time-to-contact (TTC) task. Subjects estimated when a dot moving at a constant speed would arrive at a visual landmark at varying distances after it disappeared. Subjects pressed a button when they thought the dot would contact the landmark. Subjects performed this task under three auditory conditions: rising pitch glide, falling pitch glide, and a 'no-sound' control condition. Pitch glides were linear pure-tone frequency sweeps started at the same time as the dot's movement and continued until subjects made their response. Task performance was tested for upward and downward directions in Experiment 1 and leftward and rightward directions in Experiment 2. In Experiment 1, TTC was underestimated with rising pitch and overestimated with falling pitch relative to the no-sound condition in both vertical directions, indicating that pitch modulated the speed perception of the dot. Overall TTC estimates were smaller in the downward direction yielding a larger underestimation for rising pitch compared to the upward direction, indicating an additional effect for predictive gravitational acceleration of falling objects. We found a smaller pitch effect for the horizontal directions in Experiment 2, suggesting a stronger crossmodal influence of pitch on speed in the vertical plane. Moreover, these pitch effects were not due to modulating the dot's perceived vertical spatial position. These findings suggest that when an object is not continuously visible its inferred speed can be biased by auditory pitch information during its predicted motion.

23.4071 The multisensory integration of auditory distractors and visuospatial attention

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Healthy individuals direct more attention to the left side, a phenomena known as pseudoneglect. Although visual attentional asymmetries are subtle, they have the ability to influence real-world navigational behaviour. Multisensory targets preferentially attract attention and are detected more quickly, suggesting visual attentional biases could be improved by engaging cross-modal processing. The current study examined whether left and right auditory distractors differentially impact attentional asymmetries. Participants (N=36) completed a standard perceptual landmark task to measure baseline pseudoneglect. In a second landmark task, auditory distractors were presented in conjunction with line stimuli (250ms) and participants judged which portion of the line was longer. Two blocks of trials were completed: one where 80% of distractors were presented to the left ear and one wherein 80% were presented to the right. One participant was excluded for low accuracy. Significant pseudoneglect was observed at baseline. Change scores were computed by subtracting baseline scores from bias scores for auditory distractor trials. A significant interaction between ear (left, right) and distractor frequency (tonic, phasic) occurred [$F(1, 34) = 12.932$, $p = .001$, $\eta p2 = .937$]. Pseudoneglect biases were significantly more rightward for right ear distractors, compared to left ear distractors. In the presence of left ear auditory distractors, attentional asymmetries decreased slightly, but were still leftward. For right ear distractors, attention was directed to the right of centre. Phasic right ear distractors elicited significant rightward visuospatial biases, whereas mean asymmetries were rightward for tonic right ear distractors, but not significantly so. The salience of infrequent right ear distractors led attention to be more strongly drawn toward the right side. Although participants were instructed to ignore auditory distractors, overall asymmetries were decreased by their presence. As expected, engaging cross-modal processing improved attentional asymmetries; however, infrequent distractors appear to be highly salient, and therefore capable of creating rightward asymmetries.

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23.4072 Crossmodal Attentional Blink Induced by Executive Working Memory

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Last two decades, there was a controversy whether AB (attentional blink) exists across two modalities, vision and hearing (e.g., Arnell & Jolicoeur, 1999; Hein, Parr, & Duncan, 2006). Existing models for AB and recent research suggest executive function may play a role in producing AB (e.g., Akyurek, Hommel & Joliceour, 2007; Olivers & Meeters, 2008; Arnell, Stokes, MacLean, & Gicante, 2010). This study investigated if working memory use could induce cross-modal AB. Throughout all the two experiments, a conventional paradigm which has not yielded any evident cross-modal AB (Potter, Chun, Banks & Muckenhoupt, 1998) was employed. As the cross-modal AB task, participants had to find a T1 digit (sound) and T2 digit (vision) in two simultaneous streams of rapidly presented Korean letters. In Experiment 1, participants in one group solely performed the cross-modal AB task whereas the other group was requested to memorize a set of English alphabets before the AB task. It was demonstrated that working memory

maintenance did not produce the lag effect of the cross-modal AB. Experiment 2 administered either maintenance or executive function of working memory with two groups of participants. Participants in both groups memorized a set of digits and performed the cross-modal AB task with speeded response. The task for the executive working memory group was newly introduced from Akyurek, Hommel and Jolicoeur's experiment (2007). Participants in the executive working memory group had to compare the digits in working memory with a T1 digit they heard and speedily respond whether the T1 digit matches one of the memory set digits. As a result, the cross-modal AB was induced only by the use of executive working memory with reduced T2|T1 accuracy in lag 2 and 3. The results indicate central executive function is crucial in inducing AB between the two modalities.

23.4073 **Temporal Expectation Weights Visual Signals Over Auditory Signals** Melisa Menceloglu[1](mencel@u.northwestern.edu), Marcia Grabowecky[1,2], Satoru Suzuki[1,2]; [1]Department of Psychology, Northwestern University, [2]Interdepartmental Neuroscience Program, Northwestern University

Temporal expectation is a process by which people use temporally structured sensory information to explicitly or implicitly predict the onset or duration of future events. Temporal Expectation has been shown to influence responses to stimuli in visual, auditory, and tactile modalities, but less is known about the effects of temporal expectation on crossmodal processing. Because timing plays an important role in crossmodal interaction, we investigated how temporal expectation influenced auditory-visual interaction, using an auditory-visual congruity effect as a measure of crossmodal interaction. On each trial, participants received a modality cue indicating whether a target letter, B or D, would be presented auditorily or visually. The task was to identify the letter in the cued modality as rapidly and as accurately as possible. Each target was simultaneously accompanied by either a congruent or an incongruent letter presented through the other modality. Temporal expectation was block-wise manipulated by varying the relative probability of a stimulus appearing at a short or long interval after the modality cue. In the short-interval-expected block, the short interval was used 80% of the time and the long interval was used 20% of the time. In the long-interval-expected block, the probabilities were reversed. For auditory identification, an incongruent visual stimulus produced stronger interference when the bimodal stimulus was presented with expected than with unexpected timing. In contrast, for visual identification, an incongruent auditory stimulus produced weaker interference when the bimodal stimulus was presented with expected than with unexpected timing. The fact that temporal expectation made visual distracters more potent and visual targets less susceptible to auditory interference suggests that temporal expectation increases perceptual weight on visual signals.

23.4074 **Seeing is Hearing: Integration of attended visual stimuli influence ambiguous auditory rhythm perception** Leslie Kwakye[1](lkwakye@oberlin.edu), Khalid Taylor[1], Mathew DiBiase[1], Juan Rodriguez[1]; [1]Neuroscience Department, Oberlin College

We perceive and interact with the world around us through the integration of multisensory information. While music is often considered an auditory experience, visual input can influence musical perceptions particularly in the rhythmic domain. Previous research suggests that both visual and vestibular stimuli may influence participants' perceptions of simple auditory musical beats; however, no studies have investigated the effects of visual representations of musical beats on complex acoustic rhythmic sequences. In the current experiment, participants listened to multiple 6-beat rhythms that were not clearly within either march (couplings of two beats) or waltz (couplings of three beats) musical meters and reported how they felt the rhythm coupled the beats. These auditory sequences were either unambiguous (clearly march or waltz) or ambiguous (could be perceived as either march or waltz) and presented either without a visual stimulus, with a visual march (ball bouncing on every other beat), a visual waltz (ball bouncing on every third beat), or non-matching visual beat (ball bouncing on every fifth beat). Visual march and waltz stimuli shifted participants' reports of the auditory beat; however, not all auditory sequences were equally influenced by visual march and/or waltz stimuli. This suggests that unambiguous visual stimuli play a significant but complex role in perceiving rhythms, thus highlighting the multimodal experience of music. Future studies are needed to determine the influence of musical experience on audiovisual beat perception and the neural mechanisms of this audiovisual interaction.

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23.4075 **Gluing Memories via Oscillations: Theta phase synchronization drives associative memory formation in humans** Andrew Clouter[1](aclouter@hotmail.com), Kimron Shapiro[1], Simon Hanslmayr[1]; [1]School of Psychology, University of Birmingham

The objective was to investigate the effects of neural synchrony between visual and auditory processing regions on associative memory for multisensory information. On a cellular level episodic memory formation is likely mediated by fast acting long-term potentiation which relies on the fine grained timing of neural activity. Brain oscillations, especially theta oscillations in the hippocampus, orchestrate such timing, and are a likely "gluing mechanism" for human memories. In the first experiment, in the encoding phase, all participants were shown short (3-second) videos that were luminance modified with a 4 Hz sine wave, with an accompanying audio clip that had been amplitude modulated with a 4 Hz sine wave. The phase offset (i.e. synchrony) between the audio clip and the video was 0, 90, 180, or 270 degrees. In a second experiment, the videos and sounds were modulated at 4 Hz, 1.7 Hz (delta), and 10.5 Hz (alpha). On each trial, participants rated how well the audio clip suited the contents of the video clip. Each of six blocks contained 16 audio-video pairings (four at each phase angle), and was followed by a brief distractor task and an associative recognition test. We expected that associative memory performance would vary as a function of synchrony, with better performance when the video and audio clips were both presented in synchrony compared to out-of-synchrony. Our results were in line with our expectations. We demonstrated that the formation of multisensory memories rely on the exact timing of a particular oscillatory phase that corresponds to the human hippocampal theta oscillation. This effect was observed at theta, but not at a slower (delta) or a faster (alpha) frequency. Our results therefore provide direct evidence for a causal role of theta phase synchronization for the formation of human memories.

23.4076 **Changes in audiovisual cue utilization strategy when cues become unreliable** Ryo Kyung Lee[1](ryokyung_lee@denso.co.jp), Kanji Tanaka[2], Masaru Kakizaki[1], Katsumi Watanabe[2,3]; [1]DENSO CORPORATION, [2]Waseda University, [3]University of Tokyo

In our previous study (Lee et al., VSS2015), we showed that visual dominance over auditory in spatial cuing persisted even when the cue became completely uninformative. In this study, we examined whether the visual dominance would still exist when both visual and auditory cues held only partial information but still informative to some extent. 20 participants reported the target shape (L or T), which appeared randomly either left or right side of the screen. The visual (an arrow), auditory (monaural sound), or audiovisual (an arrow and monaural sound) cues indicated the target location at given reliability levels, which decreased from 100% to 70% (5% step) in 5 sessions. Response times were longer with invalid cues. This cost in RT due to the invalid cues was inversely proportional to the reliability level and the invalid auditory cue was less likely to hinder the performance than the invalid visual or the audiovisual cues. These results confirmed that the participants tended to rely less on the auditory cues than the visual cues. However, when the cue reliability dropped to 70%, this visual dominance vanished. That is, the costs were not different between the visual and auditory cue conditions. Instead, the cost was significantly larger in the audiovisual cue condition, which shows that the participants used not only the visual cues but also the auditory cues. This result suggests that people mainly use the dominant sensory (visual) cue but switch their cue utilization strategy from unimodal to multimodal when information acquired from one sensory domain becomes unreliable.

23.4077 **An Investigation of Sound Content in Early Visual Areas** Angus Paton[1](0306402p@student.gla.ac.uk), Lucy Petro[1], Lars Muckli[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow

Early visual cortical neurons receive non-feedforward input from lateral and top-down connections (Muckli & Petro, 2013). Auditory input to early visual cortex has been shown to contain contextual information of complex natural sounds (Vetter, Smith, Muckli, 2014). To date, contextual auditory information in early visual cortex has only been examined in the absence of visual input (i.e. subjects were blindfolded). Therefore the representation of contextual auditory information in visual cortex during concurrent visual stimulation remains unknown. Using functional brain imaging and multivoxel pattern analysis, we investigated if auditory information can be discriminated in early visual areas during an eyes-open fixation paradigm, while subjects were independently stimulated with complex aural and visual scenes. We investigated similarities between auditory and visual stimuli in eccentricity mapped V1, V2 & V3 by comparing contextually-matched top-down auditory input with feedforward visual input. Lastly, we compared top-down auditory input

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to V1, V2 & V3 with top-down visual input, by presenting visual scene stimuli with the lower-right quadrant occluded. We find contextual auditory information is distinct in the periphery of early visual areas, in line with previous research (Vetter, Smith, Muckli, 2014). We also report contextual similarity between sound and visual feedback to occluded visual areas. We suggest that top-down expectations are shared between modalities and contain abstract contextual information. Such cross-modal information could facilitate spatial temporal expectations by amplifying and disamplifying feedforward input based on context (Phillips et al., 2015).

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23.4078 **Individual Variability in Real-Time Multisensory Integration** Benjamin Rowland[1](browland@wakehealth.edu), John Vaughan[1], Barry Stein[1]; [1]Department of Neurobiology and Anatomy, Wake Forest School of Medicine

The brain's synthesis of information across visual and auditory modalities confers substantive benefits to it in detecting, localizing, and identifying salient environmental events. When encountering brief and discrete cross-modal cues, the brain appears to use all of the available sensory information, and the ensuring multisensory detection and localization decisions conform to statistically optimal models of multisensory integration. The aim of the present study was to determine if and how this optimality extends to processing continuous, patterned stimuli needed to inform an ongoing behavioral task. Human participants (n=20) manually tracked the fluctuations of patterned visual (an expanding/contracting annulus) or auditory (an FM tone) stimuli in the presence of significant signal contamination. Cues were tested both individually and in combination. The frequency of oscillation in one or both modalities subtly shifted on some trials, requiring participants to detect the change(s) and shift their behavioral plan. In addition to tracking baseline performance, we analyzed the probability and rapidity with which subjects detected changes in the underlying pattern, began their shift to the new pattern, and re-established stable tracking. These performance metrics were compared across the unisensory and multisensory test conditions. The largest multisensory enhancements were observed in change-detection and the speed of shifting to the new pattern. The enhancements for most (but not all) subjects approximated predictions of the statistical optimal model. Thus, the statistical optimality of multisensory processing appears to apply not only for static cues but also continuous-time contexts.

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23.4079 **Visual and Tactile Enumeration and the Effect of Numerosity Range on Enumeration** Zahira Cohen[1](zahiraci@gmail.com), Avishai Henik[2]; [1]Department of Psychology, Ben-Gurion University of the Negev. Israel, [2]Department of Psychology and the Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev. Israel

Subitizing is a fast and accurate process of enumerating small quantities. Most studies explore visual enumeration. Thus, the question is whether subitizing is a general process that occurs regardless of modality presentation. The literature on tactile subitizing is sparse and the findings are diverse. According to our knowledge, no study has compared visual and tactile modalities using as similar a methodology as possible. We used a within-participants design to compare visual and tactile enumeration using both hands, and to explore the effect of numerosity range (NR) on enumeration. In Experiment 1, using a custom-made vibro-tactile apparatus, we replicated results of Cohen, Naparstek, and Henik (2014, Acta Psychologica, 150C, 26–34) and again found a moderate increase in RT for up to 4 stimuli and then a decrease for 5 stimuli. In Experiment 2, we compared NR 1-5 and 1-10 in tactile and visual enumeration. The results showed that enumeration for NR 1-5 was faster than for NR 1-10, especially for numerosities 4 and 5. Within NR 1-10, in the visual modality the subitizing range was 4, counting ranged from 5 to 9, and there was an end effect of 10 dots. In contrast, in the tactile modality, when excluding one-hand arrangements, the subitizing range was 2, the counting range was from 3 to 5, there was an acceleration of counting from 5 and on, and there was an end effect for 10 stimuli that was stronger than for 10 visual stimuli. We suggest that NR influences enumeration and that number-hand association (i.e., resulting from finger counting) influences enumeration, resulting in (a) faster counting for large numerosities in the tactile modality and (b) a different RT pattern for each modality.

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Face Perception: Emotion 1

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4080 **Amodal completion in facial expression aftereffect: an EEG study** Chengwen Luo[1](lcwdaisy@gmail.com), Xiaohong Lin[2], Edwin Burns[1], Zhen Yuan[2], Hong Xu[1]; [1]Division of Psychology, School of Humanities and Social Science, Nanyang Technological University, [2]Faculty of Health Science, University of Macau

The whole is greater than the sum of its parts. However, whether facial emotion perception is processed by holistic (whole) or local (parts) information is still in debate. The present study applies amodal completion to examine the contribution of holistic and local information to facial emotion adaptation. Amodal completion is ubiquitous in our daily life as we live in a clustered world. Objects that are partially occluded in a natural setting can be effortlessly perceived as complete wholes. We first generated a set of test faces whose expressions ranging from happy to sad. To manipulate amodal completion, three sets of adapting faces were also generated by manipulating the dynamics of facial parts (e.g., eyes and mouth), coherent or incoherent flickering facial parts. Participants were required to fixate on the central cross throughout the experiment. After passively exposed to the adapting amodal face, participants judged facial expression of the test faces as "happy" or "sad" on a two-alternative forced-choice (2-AFC) research paradigm via a key press, and electroencephalogram (EEG) activities was recorded simultaneously. Baseline condition without any adapting stimulus was also included. Behavioral results showed significant facial expression aftereffect when the adapting face was perceived as coherent (when amodally completion occurred), but weaker effect in the disrupted condition. The three amodal adaptors also modulate magnitude of both the early component (N170) and late components (~400ms) of the following test faces. As early component is suggested to indicate the response to the appearance of the face, and late component indicates the processing of emotinal information, our results indicate that both the local and holistic processes are critical for amodal completion in face emotion perception.

23.4081 **Rapid Serial Visual Presentation (RSVP) of Emotional Faces Generates Substantial Emotion Aftereffect as the Average Face of the RSVP Sequence** Haojiang Ying[1](ying0017@e.ntu.edu.sg), Hong Xu[1]; [1]Division of Psychology, Nanyang Technological University

Our visual system interprets myriad of visual stimuli from time to time precisely and automatically in an ensemble manner (Alvarez & Oliva, 2009), including high-level stimuli such as faces with expressions (Haberman & Whitney, 2009; Haberman, Harp & Whitney, 2009). Exposure to an emotional face can bias the judgment of facial expression of subsequently presented faces, the facial expression adaptation (Webster et al., 2004). Therefore, it is compelling to hypothesize that the exposure of a stream of faces could affect the perception of following faces as the average face of the stream does. In the present study, we tested whether adapting to the rapid serial visual presentation (RSVP, 42.5Hz) of emotional faces could generate facial expression aftereffects as their paired averaged faces. Results from Experiment 1 showed that the RSVP of faces could generate significant emotion aftereffect across both happy and sad emotions (both $p < .01$). Experiment 2 further indicated there were no significant differences between the magnitudes of adaptation aftereffects from the RSVP of faces and the average faces (both $p > .19$). These results suggested that the facial expression aftereffects from the RSVP of emotional faces and the paired averaged face were equivalent. Thus, it supports the hypothesis that our visual system applies ensemble statistics in streams of faces exposed to, and such exposure affects our perception of face emotion subsequently.

23.4082 **Face Inversion Disrupts Holistic Processing of Duchenne Emotions during Binocular Rivalry** Nour Malek[1,2](nour.malek@mail.mcgill.ca), Andy Yuan Lee Gao[1], Daniel Messinger[3], Eva Krumhuber[4], Ridha Joober[5], Karim Tabbane[5], Julio Martinez-Trujillo[1,2]; [1]Department of Physiology, McGill University, Montreal, QC, CA, [2]Robarts Research Institute, Brain & Mind Institute, and Department of Physiology & Pharmacology, Western University, London, ON, CA, [3]Departments of Psychology, Pediatrics, and Electrical and Computer Engineering, University of Miami, Coral Gables, FL, USA, [4]Departments of Cognitive, Perceptual, and Brain Sciences, University College London, London, UK, [5]Douglas Hospital Research Centre, Montreal, QC, CA

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While holistic processing is best known for the visualization of a face as a whole, its contribution to emotion perception continues to be debated. Moreover, whether intense emotions are processed differently, how this influences conscious perception, and what this may imply about the evolution of the human social brain have yet to be explored. More than a century ago, Duchenne de Boulogne suggested that wrinkles around the eyes serve as a marker for intense and genuine emotions. We hypothesized that Duchenne wrinkles are holistically encoded by the brain to preferably perceive intense and discriminate genuine facial expressions. Binocular rivalry (BR), or the competing percept during the simultaneous presentation of two monocular images, has been increasingly used to test the perceptual strength of stimuli. The longer a stimulus is perceived (larger dominance duration), the greater its perceptual strength—probably due to a stronger neural representation of that stimulus. Three natural-looking, 3-D face identities of similar skin tone and gender, each expressing five emotions (Duchenne/intense happy, happy, neutral, sad, and Duchenne/intense sad), were computer-generated and presented in a BR paradigm to 30 human participants to assess the perceptual strength of intense emotions. Duchenne facial expressions were consistently seen for significantly longer durations ($p < 1.455 \times 10\text{-}5$, Wilcoxon signed-rank test). Importantly, this effect disappeared when face stimuli were inverted, likely disrupting holistic processing ($p > 0.1451$, Wilcoxon signed-rank test). Our results indicate that intense Duchenne emotions are automatically more salient—not due to the local eye-wrinkles feature, but due to the holistic processing of the Duchenne emotion. This may suggest a core role of the Duchenne feature in the evolution of a neural mechanism to promptly distinguish intense, genuine emotions in order to effectively shape human social behavior.

Acknowledgement: NSERC, CIHR

23.4083 **When do subliminally presented expressive bodies enhance vs. inhibit facial expression processing?** Daniel Albohn[1](dna5021@psu.edu), Kestutis Kveraga[2], Reginald Adams[1]; [1]Department of Psychology, The Pennsylvania State University, [2]Department of Radiology, Harvard Medical School / Massachusetts General Hospital

Introduction: Previous work has shown that congruent combinations of non-overlapping expressive cues are integrated early in the visual process and enhance detection of faces (Adams et al., 2011). In patients with blindsight, studies have shown that congruent (vs. incongruent) pairings of subliminally presented expressive bodies in the right visual field (RVF) enhances detection of faces presented in the left visual field (LVF; Tamietto et al., 2005; 2007). Here we extend this work by examining the effect in a healthy adult sample. Additionally, we used neutral body expressions as a baseline to see if the congruent body-face detection advantage is inhibitory or facilitatory. Method: Participants (N = 23) were presented with backward-masked neutral and expressive bodies paired with a 1s exposure to expressive faces (fear/anger). Body images were always presented to the opposite VF than the expressive face. Participants were tasked with identifying the facial expression as quickly and as accurately as possible. Results: We replicated previous work showing that congruent body-face pairings are identified with higher accuracy and faster RTs than neutral body-face pairings, which in turn are identified more accurately than incongruent body-face pairings when the body was presented in the RVF. However, when the body was presented in the LVF, this advantage disappears, showing a congruency by VF interaction. Further, there was a significant main effect for VF, with bodies in the RVF showing advantageous effects overall, consistent with a right hemisphere advantage for face processing. However, for neutral body expression trials, faces were responded to with higher accuracy and faster RTs than both congruent and incongruent pairings of expressive bodies and faces when body expressions were in the LVF. Conclusion: This work suggests that congruent pairings of bodies and faces to opposite VFs may only be advantageous under certain circumstances (i.e., in the RVF).

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23.4084 **Neurodynamics of facial threat cue perception modulated by anxiety: A MEG study** Cody Cushing[1](ccushing1@mgh.harvard.edu), Reginald Adams, Jr.[2], Hee Yeon Im[1,3], Noreen Ward[1], Kestutis Kveraga[1,3]; [1]Athinoula A. Martinos Center Biomedical Imaging Massachusetts General Hospital, [2]Department of Psychology, The Pennsylvania State University, [3]Harvard Medical School

Combinations of facial expression and gaze direction can signal danger and are thus important for locating nearby threats. The amygdala complex, including the periamygdalar cortex (PAC), is a key node in the threat appraisal network. When presented briefly (300 ms), fMRI studies found a greater amygdala response to fear faces with averted gaze (Hadjikhani et al. 2008, Adams et al. 2012), which are a clear threat cue. When presentation was sustained (1 s) there was a greater amygdala response to fear faces with direct gaze, which are an ambiguous threat cue (Adams et al. 2012). This threat cue sensitivity has been found to be modulated by state anxiety: individuals with high versus low anxiety scores showed a heightened amygdala response to clear versus ambiguous threat cues, respectively (Ewbank et al. 2010). Here we sought to elucidate the neurodynamics of facial threat cue perception, and examine how they are modulated by perceiver anxiety. Participants (N=43) were shown images of fearful or neutral faces with direct and averted gaze for 1 second. Overall, source-localized MEG activity revealed an early (150-220 ms) PAC response to averted-gaze fear vs. neutral faces, and a later (700-1000 ms) rise to averted-gaze neutral faces, which appear ambiguously fearful (Ewbank et al. 2010). High-anxiety individuals showed a stronger early response to clear threat, but not a differential later response to ambiguous threat (averted neutral), whereas low-anxiety individuals had a brief early response to clear threat and a sustained late response to ambiguous threat. We also found greater responses to direct-gaze fear faces (which are an ambiguous threat cue) versus averted-gaze fear faces (clear threat cue) in PAC (~550 ms) and anterior STS (200-1000 ms). These findings suggest an early reflexive response to clear threat cues and late reflective processing of ambiguous cues that is modulated by perceiver anxiety.

Acknowledgement: R01MH101194

23.4085 **Facial expressions modulate visual features utilization in unfamiliar face identification** Daniel Fiset[1,2](daniel.fiset@uqo.ca), Josiane Leclerc[1,2], Jessica Royer[1,2], Valérie Plouffe[1,2], Caroline Blais[1,2]; [1]Département de Psychologie et Psychoéducation, Université du Québec en Outaouais, [2]Centre de Recherche en Neuropsychologie et Cognition

Flexible face identification requires extracting expression-independent visual information while leaving aside expression-dependant visual features. Most studies in the field suggest that the eye area is by far the most important visual feature for face identification (e.g. Butler et al., 2010; Schyns, Bonnar & Gosselin, 2002; Sekuler, Gaspar, Gold & Bennett, 2004). However, these studies were mostly done with stimuli showing only one (e.g. neutral) or two (e.g. neutral and happy) facial expressions. Here, we investigated the impact of facial expressions on the utilization of facial features in a facial identification task with unfamiliar faces (10 identities; 5 female). Each identity showed six different facial expressions (anger, disgust, fear, happy, neutral, sad). We used the Bubbles technique (Gosselin & Schyns, 2001) to reveal the diagnostic visual features in five non-overlapping spatial frequency bands. Twenty-five participants first learned to recognize the identities until their performance reached 95% correct for each facial expression. After reaching this performance criterion, they performed 1320 trials (220 for each facial expression) with bubblized stimuli. For each facial expression, the number of bubbles was adjusted on a trial-by-trial basis to maintain a correct identification rate of 55%. Overall, we closely replicate other studies (Caldara et al., 2005; Schyns, Bonnar & Gosselin, 2002). However, when each facial expression was analysed independently, the results show clear inter-expression differences. For neutral faces, the eyes are by far the most diagnostic features. However, for other facial expressions, participants showed a clear processing bias for expression-dependant facial features (e.g. the mouth for happy and disgust). In short, our data suggests that facial expression features are closely bound to identification in unfamiliar face recognition.

23.4086 **The left side superiority effect for facial expression perception is not a left visual field superiority effect** Chieh-An Yang[1](b01207049@ntu.edu.tw), Chien-Chung Chen[1, 2]; [1]Department of Psychology, National Taiwan University, [2]Neurobiology and Cognitive Science Center, National Taiwan University

The perception of the expression of a centrally placed face is dominated by the information from the right side of face or the left visual field. Such left superiority effect, also called left visual field superiority, has been considered as resulted from the brain lateralization for face processing. We tested this hypothesis with a split face paradigm. The face images were pictures of four individuals selected from a facial expression image database (Chen et al., 2009). We interpolated the pictures of the happy and sad expressions of the same individuals to create a series of morphed images with morphing level from 0% (sad) to 100% (happy) at 20% interval. The test stimuli were split faces with the left and the right sides at different morphing levels. The test images were presented either at the fovea, or 5 degree to the left or the right of the fixation. The task of the observer was to indicate whether the test face was sad or happy. The observers showed a strong left side superi-

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ority effect in all viewing conditions. Hence, the left side superiority is not due to a greater sensitivity to the left visual field and thus is not due to cortical lateralization for face processing. Instead, it is likely resulted from an object-based processing. The left side superiority was enhanced in the right visual field condition but reduced in the left condition. Such difference may be due to the cortical magnification that made an observer be more sensitive to the side of the image that was closer to the fixation. The left side superiority was more stable for the positive expression but declined significantly for the negative expression when the stimuli were moved from the fovea to the periphery, indicating separate mechanisms for these two types of expression.

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23.4087 The development of facial identity and expression perception

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Previous research suggests that face identity perception develops at the same rate as perception for objects (Weigelt et al., 2014). Does facial identity perception develop at the same rate as other face processing abilities, such as expression recognition? We developed matched tasks of facial identity and expression perception to assess the development of these abilities in children 5-12-years-old (n=127). The Identity task begins with a target face (2s) that is a morph between two identities (Identity A/Identity B). After a delay (400ms), the target face is replaced by two choice faces: 100% Identity A and 100% Identity B. The child must pick the choice face that is most similar to the target identity. The Expression task is matched in format and approximate difficulty to the Identity task, except the targets are morphs between two expressions (Angry/Happy, or Disgust/Surprise). The child must pick the choice face with the expression that is most similar to the target expression. We fitted probit mixed-effect models, estimated their slopes for each task as a measure of performance (better performance=steeper slope), and bootstrapped the models to obtain 95% confidence intervals. There was an effect of Age, with performance improving on both tasks with increasing age, and an effect of Task, with slightly steeper slopes for Expression (1.36) than Identity (1.20) across ages. There was no clear Task X Age interaction. Thus, perception of facial identity and facial expression appear to develop at the same rate, with equal improvement on both tasks as children get older. Given evidence that memory for facial identity develops at a different rate than memory for other objects (Weigelt et al.), we plan to adapt the tasks to determine whether memory for identity and expression develop at the same rates, providing further insight into the normal development of these face processing abilities.

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23.4088 Anger superiority effect with lines primed as faces

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In visual search tasks, angry faces are detected faster than happy faces, a phenomenon known as the anger superiority effect. However, face-like stimuli result in a comparable effect. Lines pointing inward share the orientation of the eyebrows and mouth of angry faces, and radial lines share the orientation of the features of happy faces. Interestingly, the same lines without face contour do not produce an advantage of inward lines. Because inward lines (angry-like) are detected faster than radial lines (happy-like) when surrounded by a contour, it was suggested that low-level perceptual confounds explain the anger superiority effect. Alternatively, a contour might provide a face context, predisposing observers to perceive the lines as faces. We primed observers to perceive inward and radial lines without contour as faces to create an anger superiority effect. One group performed a visual search task with schematic facial expressions (face priming) while the other performed a visual search task with shapes (no priming). Before and after the priming, we measured the anger superiority effect in both groups by asking observers to detect either inward or radial lines among horizontal lines. No contour was shown. Finally, participants were asked to label and rate the pleasantness of inward and radial lines. In the face context group, we found that observers were more inclined to label the stimuli as faces and they rated the inward (angry-like) stimuli as less pleasant than participants in the shape context group. Critically, this group was faster to detect inward lines (angry-like) than radial lines (happy-like) after priming of faces. Inward and radial lines did not differ before the search task in both groups nor after the search task in the group with no priming. Thus, the anger superiority effect originates from the better detection of threatening stimuli and not from low-level confounds.

23.4089 Are mechanisms for processing the gender and emotion of a face interdependent? Not for angry male faces.

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There is long standing interest in understanding how features of a face are represented, with behavioral and neuronal data suggesting independent as well as interdependent processing (for example, (Bestelmeyer, Jones, DeBruine, Little, & Welling, 2010; Haxby, Hoffman, Gobbini, 2000; Ng, Ciaramitaro, Anstis, Boynton, Fine, 2006). We used contingent adaptation to investigate mechanisms for processing the gender and emotion of a face. Participants (64; 18females/condition) were adapted to happy male and angry female faces (Condition1) or to angry male and happy female faces (Condition2). Adaptation consisted of 15 unique female and 15 unique male faces, happy or angry. Participants judged the emotion (angry or happy) of 4 unique male and 4 unique female faces, morphed along an emotional continuum, 80% happy to 80% angry, in a two-alternative-forced-choice design. Adaptation effects were quantified pre- and post-adaptation by fitting data with a cumulative normal to determine the point of subjective equality (PSE), the morph judged to be emotionless, supporting 50% performance. In Condition1 we found significant contingent adaptation effects; male faces were perceived angrier and female faces happier ($p < .001$). Interestingly, in the complementary Condition2 we found no significant contingent adaptation effects; both male and female faces were perceived angrier. Our results highlight how interdependent mechanisms may only emerge for certain feature combinations, especially for emotional information, given how maladaptive it is to stop responding to threatening information, with male angry faces being the most threatening. The role societal norms and early exposure have in creating such biases remain important avenues for future work.

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23.4090 Domain Specificity in the Effect of Emotion on Face and Object Discrimination

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There is an ongoing debate as to the nature of the influence of emotion on visual perception and whether such effects can be mediated by personality traits. Moreover, most exisiting studies did not evaluate whether emotional influence differs between different visual categories. Hence, the purpose of the present study was 3 fold: 1. Investigating the consequences of exposure to negative emotional visual stimuli on the sensitivity of face discrimination 2. Comparing whether such effects would differ for faces versus other visual objects and 3. Examining whether such effects would be mediated by trait anxiety. To that end, we examined the effects of negative emotional stimuli on discrimination of morphed faces and cars. A sensitive evaluation of this effect was allowed by testing participants at three levels of performance: subthresholds, thresholds, and superthresholds, predetermined by a staircase procedure. Results indicated an overall reduction in discrimination performance for both faces and cars following exposure to negative emotional stimuli, compared to those following neutral ones. However, an interesting dissociation was revealed between the vulnerability of the perceptual system when discriminating cars versus when discriminating faces. For individuals with high trait anxiety, performance in the car task substantially declined under the negative emotion condition, resulting in an equally worse performance at the thresholds and the subthresholds levels. Performance in the face task, in contrast, although also adversely affected, showed some resilience with accuracy rates at the thresholds levels remaining consistently higher than those at the subthresholds level. This pattern of a more detrimental effect of negative emotion on the discrimination of cars was not shown for individuals with low trait anxiety, who were overall less affected. These results may suggest that the perceptual system is more resistant to perturbation when processing faces compared to other classes of visual objects.

23.4091 Happiness Detection in Periphery Less Difficult than Anger Detection

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Facial emotion detection involves recognizing the appropriate facial features associated with the emotional state of the target. The emotional content of a facial stimulus presented in one's periphery is less salient than the emotional content of that same face when presented centrally. As a result, emotion detection in the periphery is more challenging. Angry, happy, and neutral facial expressions were presented at varying eccentricities – 5, 10, 15, and 20 degrees – from the center of the display for 250 ms simultaneously with a central stimulus. Facial stimuli were presented on both the left and right side of the display, and participants judged the gender or the emotional content of each face. For the emotion detection task, facial stimuli were blocked by emotion such that participants viewed neutral and angry stimuli or they viewed neutral and happy stimuli. The purpose of the central stimulus was to maintain the participants' focus on the center of the display. Participants' responses on trials in which they correctly classified the central stimulus were analyzed. Accurate gender detection and anger detection declined as the facial stimuli were presented further into the periphery by about 2.5% per degree of eccentricity. Detection of happiness remained relatively stable at larger eccentricities from the center of the display, ultimately declining by less than 1% per degree of eccentricity. Overall mean levels of emotion discrimination were also substantially higher for happy expressions than for angry expressions, relative to neutral (d' difference of 0.74 to 1.70 depending upon eccentricity). These findings are consistent with prior research demonstrating that, when presented in the periphery, facial features that are important for emotion recognition may be more salient and easier to interpret for happy expressions than for negative emotional expressions.

23.4092 **Does early processing of low-spatial frequency fearful facial expressions vary as a function of autistic tendency?** Laila Hugrass[1](lhugrass@swin.edu.au), Adelaide Burt[1], Tasha Firth-Belvedere[1], David Crewther[1]; [1]Faculty of Health Arts and Design, Swinburne University of Technology

Processing of fearful facial expressions occurs via both cortical and subcortical routes. Evidence from event related potential (ERP) research suggests that fearful facial expression influences neural activity as early as 100ms. More specifically, these early activations appear to reflect processing of low spatial frequency information via a magnocellularly driven subcortical route. Based on evidence of differences in visual processing across the autistic spectrum, we suggest that rapid processing of low spatial frequency fearful faces may vary as a function of autistic tendency. Here we compare ERP responses to low and high spatial frequency fearful expressions for groups of neurotypical individuals with low cf high levels of autistic tendency. Visual ERPs were collected for two (neural/fearful) by two (low/high spatial frequency) sets of hybrid face stimuli, all of which were matched for luminance and root-mean-square contrast. Consistent with previous evidence, ERP P100 response amplitudes were greater for fearful cf neutral faces and this effect was specific to low-spatial frequency fearful expressions. Interestingly, processing of low and high spatial frequency fearful expressions differed across AQ groups. In the low AQ group, N170 amplitude was greater for low-spatial frequency fearful expression, whereas in the high AQ group, N170 amplitude was greater for high-spatial frequency fearful expression. These results suggest that even within the neurotypical population, autistic tendency affects subcortical processing of low-spatial frequency fearful expression. Hence, differences in emotional face processing across the autistic spectrum may be explained by early visual processing biases in the magnocellular and parvocellular pathways.

23.4093 **Distinct roles of the anterior temporal lobe and the inferior frontal gyrus in recognition of dynamic emotional body expressions in patients with frontotemporal dementia** Jan Jastorff[1](jan.jastorff@med.kuleuven.be), François De Winter[1], Martin Giese[2], Mathieu Vandenbulcke[1]; [1]Laboratory for Translational Neuropsychiatry, Research Group of Psychiatry, Department of Neuroscience, KU Leuven, Belgium, [2]Section for Computational Sensomotorics, Department of Cognitive Neurology, University Clinic Tübingen, 72076 Tübingen, Germany

One of the most critical components to social behavior is the recognition of the emotional states of others. Consequently, numerous cortical and subcortical brain regions are involved in the processing of emotional signals from conspecifics. To gain causal evidence regarding the role these areas play in emotion perception, we investigated emotion processing in patients diagnosed with the behavioral variant of fronto-temporal degeneration (bvFTD), combining behavioral testing and structural and resting state fMRI imaging in patients, with functional imaging in young healthy volunteers. 14 bvFDT patients performed a behavioral emotion recognition task (4 emotions) using dynamic body expressions generated by motion morphing as stimuli. The task involved a first emotion detection, and a second emotion categorization stage. Compared to controls, patients were significantly impaired in both tasks, whereas they showed no difference in performance in a control task testing emotionally neutral motion morphs between walking and running. Interestingly, performance in the two tasks correlated with distinct regional atrophy: Gray matter volume in the left anterior temporal lobe (ATL) correlated with emotion detection, whereas atrophy in the left inferior frontal gyrus (IFG) correlated with emotion categorization performance in patients. Investigating emotion decoding performance using MVPA analysis of functional data from healthy controls performing the same task in the scanner supported the potentially crucial role of the two regions. Whereas both, ATL and IFG, allowed for decoding of emotional stimuli compared to neutral stimuli (emotion detection), only IFG allowed decoding of which emotion was shown (emotion categorization). Resting state fMRI analysis comparing patients with age matched controls showed reduced connectivity between ATL and IFG, ATL and mid and posterior temporal regions, IFG and insular and IFG and amygdala. These results highlight the specific functional roles that the anterior temporal lobe and the inferior frontal gyrus play in emotion perception from body movements.

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Objects: Mechanisms and models 1

Saturday, May 14, 8:30 am - 12:30 pm
Poster Session, Pavilion

23.4094 **The medial axis as a robust model of object representation** Vladislav Ayzenberg[1](vayzenb@emory.edu), Sami Yousif[1], Stella Lourenco[1]; [1]Department of Psychology, Emory University

The algorithm with which humans represent objects must be durable enough to support object recognition across changes in orientation and partial occlusions. This algorithm must also be flexible enough to include both internal components of an object and its global shape. The current study examined viable models of object representation. In a first experiment, we tested the medial axis model (i.e., shape skeleton; Blum, 1973) against a principal axis model (Marr & Nishihara, 1978) with three shapes (rectangle, square, and T) using the "tap" paradigm by Firestone and Scholl (2014) where participants were instructed to tap once within a shape anywhere they choose. We collected 200 taps per shape and found that responses were significantly closer to the medial axis than either randomly-determined points (best set of 50,000 simulations; ps < .001) or points corresponding to the major principal axis (ps < .001). Having found evidence for the medial axis model, in a second experiment we tested whether an internal protrusion of varying size affected participants' the medial axis representation of a rectangle. Participants tapped within a rectangle that contained either a large or small visible obstacle within it. We found that in both cases, participants' taps conformed to the medial axis of the shape (p < .001); that is, taps accommodated to the obstacle within the rectangle. Taken together, these results provide evidence for a robust medial axis representation that is both evident for different shapes and one that flexibly accommodates to even slight protrusions within a shape.

23.4095 **Target detection within a two-dimensional shape: A test of the medial axis model of object recognition** Samoni Nag[1](samoni.nag@emory.edu), Vladislav Ayzenberg[2], Sami Yousif[1], Stella Lourenco[2]; [1]Department of Psychology, Emory College of Arts and Sciences, Emory University, [2]Department of Psychology, Laney Graduate School, Emory University

Humans recognize objects across different viewpoints with remarkable ease. Yet much remains unknown about how the visual system accomplishes this incredible feat of recognition. One intriguing proposal is that object recognition is so efficient because vision relies on a representation of the medial axis, or the so-called shape skeleton (Blum, 1973; Firestone & Scholl, 2013). Support for this proposal comes from research demonstrating that humans have an attentional bias for the medial axis when tasked with tapping anywhere they would like inside a shape (Firestone & Scholl, 2014). However, there exists very little behavioral evidence that further confirms the existence of a medial axis representation. The current study provides converging evidence for the medial axis model by demonstrating its existence in a novel context. Using a visual search paradigm, we tested whether target detection within a rectangle was faster along the medial axis. Participants were tasked with detecting a darker square among an array of distractor squares (132 total) arranged in a rectangle. For each participant, the shade of the target was titrated using a color sensitivity task that also served as training. Reaction times (RTs) were recorded

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for all targets within the rectangle. Preliminary results indicate that participants are faster at detecting targets that are located along the medial axis of the rectangle in comparison to other (i.e., non-medial axis) points in the array ($p < .05$). Moreover, RTs decreased as a function of target distance to the medial axis; that is, the closer the target was to the medial axis, the faster participants' detected it ($p < .001$). These findings provide further support for a medial axis model of object recognition and expand on previous studies that have shown enhanced contrast sensitivity of Gabor filters along the medial axis of a shape (Kovács & Julez, 1994; 1998).

23.4096 **Letters, faces, and dots--oh my! A connectionist account of lateralization in vision.** Benjamin Cipollini[1](bcipolli@ucsd.edu), Vishaal Prasad[1], Garrison Cottrell[1]; [1]UC San Diego Department of Computer Science and Engineering

The left and right sides of the brain differ in how they process visual stimuli such as words & faces, local & global aspects of Navon stimuli, high & low frequency gratings, even illusory contours. Our "differential encoding" autoencoder model suggests these differences can be explained by an asymmetry in the average length of long-range lateral connections, which are known to be involved in contour and shape processing. Our model accounts for more types of stimuli than competing models (e.g. the Double Filtering by Frequency (DFF) model), and makes a testable prediction about neural differences underlying lateralized visual processing. Here we account for two important phenomena our model has not been tested on. Two experiments show lateralization in coordinate and categorical discriminations. Coordinate discriminations require judging continuous distances and show right hemisphere (RH) dominance; categorical discriminations simply require classification of visual stimuli and show left hemisphere dominance (LH). Another two experiments examine response changes after "contrast balancing" stimuli. There, dark lines are outlined by thin bright lines, suppressing low frequency information while preserving the percept of shape and contour. Contrast balancing abolishes the "global precedence" effect (where the global level in Navon stimuli is processed faster than the local level), and suppresses most (not all) asymmetries. Across these experiments, our model shows LH dominance for categorical tasks and RH dominance for coordinate tasks. This asymmetry in our model is abolished by contrast balancing. Beyond these general patterns, our model closely matches the patterns for specific stimuli in each experiment. In addition, contrast balancing abolishes asymmetric processing of Navon stimuli in our model and removes the global precedence effect. Compared to the DFF model, our model fits the data better, accounts for more data, and uses a mechanism that could explain how asymmetry can survive contrast balancing. We plan to examine such data next.

23.4097 **The picture morphing task – an efficient and quick means to measure updating** Elisabeth Stöttinger[1](estoettinger@uwaterloo.ca), Eva Rafetseder[2], Britt Anderson[1,3], James Danckert[1]; [1]University of Waterloo, [2]University of Stirling, [3]Centre for Theoretical Neuroscience, University of Waterloo

We report the results of three studies using a picture morphing task. We argue that this task is an effective, easy to administer, and widely applicable assessment tool for probing the ability to update perceptual representations. By presenting a series of fifteen images that morph from one unambiguous object (e.g., rabbit) to a completely different object (e.g., duck), we can assess the time and evidence necessary for perceptual re-categorization in children, brain-damaged adults, and normal adult controls. Study one presented 3 and 5 year old children with a version of the picture morphing task and a Theory of Mind assessment (i.e., False Belief Task). The picture morphing task could be performed by both age groups. Within the 5-year old group, children who passed a False Belief Task and were able to correctly explain why, showed faster perceptual updating. Study two demonstrated that damage to the right hemisphere – especially the right anterior insula – resulted in an updating impairment; these patients requiring significantly more pictures before they reported the new object compared to left brain damaged patients. In study three, an fMRI experiment with healthy individuals, the anterior insula and mid-frontal regions were activated at the time when a change was reported, and immediately before. In summary, the picture morphing task offers an an efficient tool for measuring updating mental representations in vastly different experimental settings and participant populations.

23.4098 **Crowding area sets a lower bound on the neural noise that limits letter identification** Hörmet Yiltiz[1](hormet.yiltiz@nyu.edu), Xiuyun Wu[1], Denis Pelli[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

We report a connection between effects of crowding and noise. In the periphery, it is impossible to identify a target in clutter, unless the clutter is at least a critical spacing away. The area enclosed by the critical spacing is the "combining field". Measuring thresholds in various levels of full-field white noise, we decompose threshold contrasts into efficiency and equivalent input noise (Pelli & Farell, 1999). Efficiency is the fraction of the contrast energy used by the human observer that would be needed by an optimal algorithm in the same amount of noise. Equivalent input noise is the amount of display noise needed to account for the human threshold, given the measured efficiency. We presented a 0.5, 2, or 8 deg letter at an eccentricity of 0-32 deg on a full-field background of white noise, at one of several noise contrasts. Measured threshold contrasts were decomposed into efficiency and neural noise. We find that efficiency is independent of eccentricity (0 to 32 deg) for all letter sizes within the acuity limit. For letters larger than the combining field, neural noise is proportional to letter area and independent of eccentricity. For letters smaller than the combining field, the neural noise corresponds to the combining field area, which is independent of letter size and grows with eccentricity. The foveal finding of equivalent noise proportional to area is consistent with scale-invariant letter recognition. The break of that proportionality in the periphery occurs when letter size equals combining field size, suggesting that there is a neural channel with that area, and perhaps there are similar channels with larger (but not smaller) areas.

23.4099 **The time course of structure-based and function-based action representation activation during object recognition** Wenyuan Yu[1,2](yuwy@psych.ac.cn), Ye Liu[1], Xiaolan Fu[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, [2]University of Chinese Academy of Sciences

Previous research has proved that the action representation influences object recognition before the completion of object recognition, that is, within the first 150 millisecond (Kiefer, Sim, Helbig, & Graf, 2011). There are at least two kinds of action representation, structure-based and function-based action representation, depending on different neural streams (Rizzolatti & Matelli,2003). Therefore, an ERP experiment was conducted to explore whether these two action representations can both influence object recognition before the completion of object recognition. With a priming paradigm, a hand posture picture and a manipulable object were presented sequentially and participants were asked to name the object when a question mark was presented, during which ERPs were measured to examine brain activation. The results showed that there was a function-based action priming effect over the central scalp as early as 70 millisecond after the onset of target objects, that is, the mean amplitude with congruent function-based action pictures was significant larger than that with incongruent function-based action pictures in central scalp. Whereas, the difference between congruent and incongruent trials was not significant in structure-based action priming condition. The mean amplitude of N1 in the function-based action priming condition over the parietal scalp in the early stage of object recognition was significant larger than that in the structure-based action priming condition. These results indicate that function-based action representation is activated in the early recognition stage, and functions before the completion of object recognition, while the structure-based action representation cannot. The findings suggest that the activation time of these two action representation are different and that function-based action representation is perhaps more important to object recognition. The present study provides further evidence for the distinction between two action systems: "Grasp" and "Use" system.

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23.4100 **Feature representations in networks trained with image sets of animate, inanimate or scenes differ in terms of computational filters but not in location in the brain** Max Losch[1,3](M.M.Losch@uva.nl), Noor Seijdel[1], Kandan Ramakrishnan[1,2], Cees Snoek[2], H.Steven Scholte[1,3]; [1]Brain & Cognition, Psychology, University of Amsterdam, [2]Institute of Informatics, University of Amsterdam, [3]Amsterdam Brain & Cognition, University of Amsterdam

With the rise of convolutional neural networks (CNN's), computer vision models of object recognition have improved dramatically in recent years. Just like the ventral cortex, CNN's show an increase in receptive field size and an increase in neuronal tuning when you move up the neural or computational hierarchy. Here we trained a CNN with an Alexnet type architecture (Krizhevsky et al., 2012) using three different image sets (scenes, animate, inanimate). Next we evaluated the responses in the layers of these networks towards 120 images (images selected from ImageNet (Deng et al., 2009) and Places205 (Zhou et al., 2014)) using these networks and the original Alexnet. We observe, starting in the third convolutional layer, a

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differential pattern in the features that have emerged from the networks. The original Alexnet in contrast has a wide range of features spanning all other feature spaces. The features from the place network are a small cluster within this space containing features such as building facades, ground-textures and some human faces. Directly next to this cluster are features from the inanimate trained network that respond to elements such as textile textures, tools and objects. The features from the animate network are much more scattered and respond mainly to faces (humans and other animals). We also evaluated the brain responses towards these images using BOLD-MRI, focusing on the ventral cortex. Using representational similarity analysis we observed reliable correlations of these networks in LO1, LO2, VO1 and VO2 without a spatial differential pattern. These show that specialized trained networks result into specialized features. These features appear to be also used by the brain but within the same general architecture.

23.4101 How well do Deep Neural Networks model Human Vision?

John Clevenger[1,2](jcleven2@illinois.edu), Diane Beck[1,2]; [1]Department of Psychology, University of Illinois, [2]Beckman Institute for Advanced Science and Technology, University of Illinois

Recently there has been dramatic improvement in computer-vision object recognition. In the 2015 ImageNet challenge, the best performing model (GoogLeNet) had a top-5 classification accuracy of 93%, a 20% improvement over 2010. This increase is due to the continued development of convolutional neural networks (CNN). Despite these advances, it's unclear whether these biologically-inspired models recognize objects similarly to humans. To begin investigating this question, we compared GoogLeNet and human performance on the same images. If humans and CNNs share recognition processes, we should find similarities in which images are difficult/easy across groups. We used images taken from the 2015 ImageNet challenge, spanning a variety of categories. Importantly, half were images that GoogLetNet correctly classified in the 2015 ImageNet challenge and half were images that it incorrectly classify. We then tested human performance on these images using a cued detection task. In order to avoid ceiling effects, the images were briefly presented (< 100 ms, determined per subject) and masked. A category name was shown either before or after the image and people were asked whether or not the image matched the category (which it did half the time). We found that people required 2.5 times more exposure time to recognize images when the category was cued before the image rather than after, consistent with a role for top-down knowledge/expectation in human recognition. However, at the image-level accuracy was highly correlated across pre and post-cues ($r = .82$), indicating that some images are harder than others regardless of how they are cued. Importantly, people were substantially better at recognizing the images that GoogLetNet correctly (85%) rather than incorrectly (58%) categorized. This might be suggestive of shared processes. However, within the set of images that GoogLeNet got incorrect, human performance ranged from 9% to 100%, indicating substantial departure between human and machine.

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23.4102 Learning Deep Representations of Objects and Materials for Material Recognition

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We study the problem of recognizing the material of an object from its single image. We are interested in how representations learned by convolutional neural networks (CNNs) for object recognition can be transferred for material recognition.We first propose a procedure for transfer learning using a 16-layer CNN model. First, it is trained for object recognition using a dataset of object images (ImageNet). Then, the model is fine-tuned for material recognition using a material dataset created in the authors' lab, which is an extended version of FMD dataset (Sharan et al., IJCV, 2013). The dataset (named EFMD) consists of 10,000 images belonging to the same 10 classes as FMD. Finally, while fixing from 1st to 9th layers, only 10th to 16th layers of the model are further fine-tuned using a training subset of FMD. The model obtained by this procedure achieves prediction accuracy 83%±0.99 on FMD, which is close to the reported human performance 84.9%. In addition, we analyze the effect of representations of local and non-local surface properties on performance by employing models on deformed images of FMD. First, we use two datasets, namely t15 and t30, consisting of images that are deformed "locally" using synthesized texture forms with 15x15 and 30x30 patches, respectively. Then, we use two datasets of images deformed to emphasize non-local properties of surfaces using bilateral and high-pass filters, called bf and hf, respectively. The proposed procedure provides 65.3%±1.13, 69.8%±0.82, 69.2%±1.00, and 64.7%±1.90, while the human performance is reported as 38.7%, 46.9%, 64.8%, and 65.3% on t15, t30, hf, and bf, respectively. This result can be attributed to the locality of representations learned in CNNs implied by the local convolutions. Overall, our results suggest that object representations can be transferred for learning material representations in CNNs to model local surface properties and recognize materials.

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23.4103 Biologically plausible Hebbian learning in deep neural networks: being more close to the nature than CNNs.

Michael Teichmann[1](michael.teichmann@informatik.tu-chemnitz.de), Fred Hamker[1]; [1]Department of Computer Science, Technische Universität Chemnitz

Convolutional neural networks (CNN) are today the best model at hand to mimic the object recognition capabilities of the human visual system. However, this kind of models lack some biological plausibility in terms of learning and network architecture. With the goal in mind to provide a realistic, but also powerful model to study the function of the human visual system, we propose a biologically-plausible implementation of a deep neural network. We combined, excitatory and inhibitory rate coded neurons in a recurrent network of V1 (L4, L2/3) and V2 (L4, L2/3), with Hebbian synaptic plasticity, intrinsic plasticity, and structural plasticity. The connectivity between layers is modeled based on anatomical data of the neocortical circuit (Douglas & Martin, 2004, Potjans & Diesmann, 2014). The network learns from natural scenes invariance and feature selectivity in parallel. We demonstrate the functioning of the model by three different kind of evaluations: (I) Its object recognition performance on the COIL-100 dataset. We obtained good accuracies (99.18±0.08%), using a SVM with linear kernel on top. The network shows increasing recognition accuracies in deeper layers, matching the hypothesis that the neural code becomes more and more untangled in terms of linear pattern separability (DiCarlo & Cox, 2007). (II) We show that the learned receptive fields fit the physiological data of V1 (Ringach, 2002). (III) The network is demonstrated to match the recent hypothesis that V2 is sensitive to higher-order statistical dependencies of naturalistic visual stimuli (Freeman et al., 2013). We measured the neuronal responses on synthetic naturalistic textures in comparison to spectrally-matched noise and found similar results as in the neurophysiological data: V2-L2/3 neurons prefer naturalistic textures as against spectrally-matched noise, whereas V1 shows no preference. Therefore, we suggest that the functioning and design of the presented model makes it an appropriate platform for studying the visual cortex.

23.4104 Macroanatomical alignment improves the intersubject consistency of cytoarchitectonic regions in the human ventral stream

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Eight cytoarchitectonic regions (cROIs) have been identified in the human ventral stream including the primary visual cortex and and higher visual areas (Amunts et al., 2000; Rottschy et al., 2007, Caspers et al., 2013; Lorenz et al., 2015). While hOc1 is consistently located in the calcarine sulcus (Fischl et al., 2008), it is unknown whether such a correspondence between cROIs and anatomical landmarks persists in higher-level regions. We hypothesized that if such a correspondence exists, cortex-based alignment (CBA) of cROIs will yield better consistency across subjects than volume-based alignment. Each of the 8 cROIs was projected to the cortical surface of each subject's brain. We then generated a group map of each cROI by transforming individual subjects' cROIs into a common anatomical space (Figure 1) using three types of alignments: (1) volume-based alignment to the MNI template, (2) CBA to a template cortical surface, either the Freesurfer average brain (CBAfs) or average of the 9 PM brains (CBApm), and (3) CBA with additional constraints of the mid fusiform sulcus and collateral sulcus (CBApm+MFS+CoS). We examined which method produced the most accurate group cROI. Results show that CBAfs and CBApm alignments significantly improve the across-subject correspondence of the 8 cROIs compared to volume alignment ($F(2,34) = 31.418$, $p < .001$, Figure 2). Further, adding the MFS and CoS to the alignment significantly reduces inter-subject variability in the location of the FG1/FG2 boundary ($p < .05$, permutation test, Figure 3) but not the FG3/FG4 boundary compared to both CBA approaches, Overall, these results suggest that CBA generates more accurate atlases of the cytoarchitectonic structure of the ventral stream by preserving the location of cROIs relative to the cortical folding. Further, adding ventral stream sulci as constraints to the CBA improves the accuracy of localizing the boundaries between cROIs

Acknowledgement: 1R01EY02391501A1

23.4105 **Surfaces are factored out of patterns by monkey IT neurons** N. Apurva Ratan Murty[1](ratan@cns.iisc.ernet.in), S.P. Arun[1]; [1]Centre for Neuroscience, Indian Institute of Science

We have no difficulty recognizing a straight line on a tilted or curved surface, but this inference is in fact non-trivial. Doing so requires factoring out the overall surface deformation from the pattern itself, a process whose underlying neural mechanisms have never been investigated. Here, we recorded the responses of single neurons in the monkey inferior temporal (IT) cortex to stimuli in which the pattern and the surrounding surface were varied independently. In a subpopulation of IT neurons, we found surface-pattern interactions that produced similar responses when the pattern and surface were congruent. These interactions arose late and produced opposite modulation for pattern and surface changes, in a manner akin to surround suppression. This was true for patterns on a variety of surfaces: flat, tilted, rotated, convex and concave. Thus, surface deformations are factored out of pattern representations by monkey IT neurons.

Motion: Depth and form

Saturday, May 14, 8:30 am - 12:30 pm

Poster Session, Pavilion0

23.4106 **Decoding direction of binocular motion from human visual cortex** Andrew Haun[1](amhaun01@gmail.com), Jacqueline Fulvio[1], Martijn Barendregt[2], Bas Rokers[1]; [1]Department of Psychology, University of Wisconsin-Madison, [2]Helmholtz Institute, Utrecht University

To perceive 3D motion, 2D motion signals from the two eyes must be combined. Previous work has shown that 2D motion direction can reliably be decoded from MRI BOLD activity throughout visual cortex. 3D motion presents a special case for motion encoding and decoding, since 2D motion direction can be inferred from monocular signals, but 3D motion requires that signals from both eyes are combined. Here we investigated if 3D motion direction can be reliably decoded from visual cortex. We measured the BOLD response (3 mm isotropic resolution) of human visual cortex to binocular stimuli moving in one of eight directions (leftward/rightward, approaching/receding, and the 4 intermediate directions), while observers performed a fixation task. The approaching/receding stimuli avoided the possibility of being decoded from spatiotopic cues, known to facilitate decoding of 2D motion direction (Wang, Merriam, et al, JoN 2014). We subjected the BOLD response to MVPA decoding analyses (ROI-wise or searchlight-wise). We found that the BOLD response is highly informative about 2D direction across visual cortex (V1, V2, V3, MT+, and beyond), replicating previous findings. BOLD response is less informative about 3D direction, with information concentrated in later areas (V3, MT, IPS). Interestingly, decoding errors for the direction of 3D motion mirror the typical perceptual errors in the perception of 3D motion (Fulvio, Rosen & Rokers APP 2015). Specifically, approaching and receding directions tend to be confused both perceptually and by the decoder. These results suggest that 3D motion is encoded by later visual areas. The limitations in spatial resolution of the BOLD signal are consistent with poor 3D motion decoding in V1. Finally, the neural and behavioral confusion of 3D motion stimuli may have a common basis.

23.4107 **Global eye-specific motion signal for three-dimensional motion processing revealed through adaptation** Devon Greer[1](greer.devon@gmail.com), Sung Jun Joo[1,3,4], Lawrence Cormack[1,2,3], Alexander Huk[1,2,3,4]; [1]Center for Perceptual Systems, The University of Texas at Austin, Austin, TX, USA, [2]Institute for Neuroscience, The University of Texas at Austin, Austin, TX, USA, [3]Department of Psychology, The University of Texas at Austin, Austin, TX, USA, [4]Department of Neuroscience, The University of Texas at Austin, Austin, TX, USA

The visual system uses interocular velocity differences (IOVDs) to compute three-dimensional (3D) motion. In most models, the monocular 2D motion signals are extracted and combined at the early stage of visual processing (i.e., V1) where eye-of-origin information is still available. However, we have demonstrated that observers can use eye-specific 2D motion information to judge 3D motion direction, suggesting that eye-specific information might be available for 3D motion computation at later stages of visual motion processing (Rokers et. al., JOV, 2011). Stimuli consisted of 60 small (~1°) drifting Gabors displayed inside an annulus (3° - 7° eccentricity). In Experiment 1, we measured 2D MAEs with test stimuli presented in unadapted locations. We predicted and confirmed that there would be little, if any, 2D MAEs because the receptive field (RF) size of V1 neurons is small and MT inherits direction-selectivity from V1. In Experiment 2, we measured 3D MAEs in which adapting stimuli were Gabors drifting in opposite directions in the same retinal locations between eyes. Test stimuli were the same as adapting stimuli except presented in unadapted locations. We found robust 3D MAEs, suggesting that 3D MAEs are not due to by local motion processing that presumably occurs in V1 and 3D direction selectivity arises at later stages of visual processing with larger RFs. In Experiment 3, we used a stimulus configuration where Gabors in each eye did not share the same retinal location. We found strong 3D MAEs, suggesting eye-specific 2D motion information is preserved at later stages of visual processing to compute 3D motion. Our results demonstrate that the locus of 3D motion computation might be late in the visual hierarchy, at least after V1, and unlike previous views, eye-specific motion information is available for 3D motion computation at later stages of visual processing.

Acknowledgement: NIH NEI Grant EY020592

23.4108 **The perception of depth vs. frontoparallel motion assessed by continuous target tracking** Kathryn Bonnen[1,3](kathryn.bonnen@utexas.edu), Alexander Huk[1,2,3], Lawrence Cormack[1,2,3]; [1]Institute for Neuroscience, University of Texas at Austin, [2]Department of Psychology, University of Texas at Austin, [3]Center for Perceptual Systems, University of Texas at Austin

We used 3D tracking to simultaneously assess the perception of motion in all directions (horizontal, vertical, and depth). Despite the ecological importance of perceiving motion-through-depth, we found that tracking performance for depth motion was poor compared to frontoparallel motion. Moreover, this impairment was greater than predicted from the small relative size of the retinal signals arising from depth motion. Target-tracking relies on a simple intuition: the better one can see an object or its motion, the more accurately one can point to it. In the main experiment, subjects pointed with their finger to track a stereoscopic luminance circle as it moved in a 3-dimensional Brownian random walk. We measured tracking performance by calculating cross-correlograms for each cardinal motion axis. Tracking performance was selectively impaired for depth motion compared to horizontal and vertical (frontoparallel) motion. The retinal projections resulting from depth motion are, due to geometry, much smaller than those arising from frontoparallel motion, given the same environmental motion extent. In a second experiment, observers tracked a stereoscopic luminance circle as it moved in a one-dimensional Brownian random walk either in depth or horizontally. We systematically manipulated the size of the retinal projection of the motion. This allowed us to isolate a component of the impairment that was independent of signal size. Further experiments ruled out motor explanations. In a final experiment, observers tracked a disparity-defined target in a dynamic random element stereogram as it moved in a 3-dimensional Brownian random walk. When frontoparallel tracking required a disparity computation, tracking performance suffered in a manner similar to the isolated component observed in the retinal projection experiment. Despite the crucial importance of egocentric depth motion, its perception is impaired relative to frontoparallel motion beyond what would be expected from viewing geometry. Disparity processing provides a possible explanation for this impairment.

Acknowledgement: NIH NEI EY020592 (LKC, ACH) NSF GRFP DGE- 1110007 (KB) Harrington Fellowship (KB)

23.4109 **The effect of frame rate and motion blur on vection** Yoshitaka Fujii[1](fujii@cse.yorku.ca), Robert Allison[1], Pearl Guterman[1], Laurie Wilcox[1]; [1]Centre for Vision Research, York University

Immersive cinema relies on vision to orient and move the viewer through the portrayed scene. However some viewers are susceptible to cinema sickness, which has been linked to visually-induced percepts of self motion or vection. Recent advances have enabled cinematic frame rates much higher than the conventional 24 frames per second (fps). The resulting improved motion fidelity might promote vection with potentially positive (e.g., increased presence) or negative (e.g., cinema sickness) consequences. We measured the intensity of vection while observers watched stereoscopic 3-D computer graphics movies projected on a large screen. We fixed the refresh rate at 120 Hz (60 Hz per eye using shutter glasses), and manipulated the flash protocol to create 60 fps (single flash), 30 fps (double flash) and 15 fps (quadruple flash) for each eye. The stimuli simulated forward motion along a gently winding street at speeds of 20 and 40 km/h. The simulated camera exposure time was also varied (0, 8.33, 16.67 and 33.33 ms) to investigate effects of motion blur. Vection intensity was measured using a magnitude estimation technique for all conditions interleaved randomly. Results from eighteen observers showed that vection intensity was significantly higher at a simulated speed of 40 km/h than at 20 km/h, but there was no main effect of exposure time. For the no motion blur condition (0 s) at the slower speed, stronger vection was observed at higher frame rates as predicted. The lack of an effect of frame rate at the high speeds may have been due to a ceiling effect, as vection was much stronger in the fast conditions. The lack of influence of frame rate in the presence of motion blur is interesting and suggests that motion artefacts (such as judder) that are introduced at low frame rates could be hidden by motion blur.

Acknowledgement: NSERC CUI2I 437691-12

23.4111 **How independent are global form and global motion processings ?** Simon Clavagnier[1](simon.clavagnier@mcgill.ca), Vanessa Polito[1], Robert Hess[1]; [1]McGill Vision Research Unit, Departement of Ophthalmology, McGill university, Canada

It is considered that resolving global form involves processes taking place in the ventral visual pathway whereas resolving global motion involves processes taking place in the dorsal visual pathway. It remains unclear whether the two pathways interact or are independent of one another. We determined whether our ability to discriminate motion direction on a global motion coherence task was affected by the amount of global orientation coherence, and vice versa. The experiment was designed such as the same visual stimuli contained both orientation and motion information. It consisted in a set of 100 oriented gabors randomly placed within the 8 degrees of eccentricity that independently moved at 2 deg/s. Signal Gabors had either horizontal or vertical orientation and left/right motion direction, whereas noise Gabors had random orientation and random direction of motion. Subjects were informed of which information to respond to (orientation or motion) by a visual cue that was shown either before or after the presentation of the stimulus. The results based on 3 subjects showed that orientation information did affect performance on global motion and motion information did affect performance on global orientation, arguing in favor of two independent processes. Presenting the task cue before or after the visual stimulus did not change the performances.

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23.4112 **Motion-from-Form perception in Scotopic and in Photopic light conditions** Mariagrazia Benassi[1](mariagrazia.benassi@unibo.it), Tony Pansell[2], Roberto Bolzani[1], Kerstin Hellgren[2], Luca Mandolesi[1], Sara Giovagnoli[1]; [1]Department of Psychology, University of Bologna, [2]Department of Clinical Neuroscience Karolinska Institutet, Stockholm

Human visual perception is globally worsened under dim light condition. The aim of this study was to investigate how rod-dominated vision affects motion perception in a motion-from-form (MFF) and motion coherence (MC) task. Thirty healthy subjects (11 males, mean age 21.3 years) participated in the experiment. MFF and MC were tested both in scotopic and photopic light conditions. Both the MFF and MC stimuli consisted of nine empty circles moving coherently at a constant velocity of 10.7°/sec in one of eight directions (cardinal and oblique). Five noise-levels were used: starting from zero, the noise increased by 6 units in each following level. In the MFF test 169 empty white squares acted as stationary background. Nine target-stimuli were drawn in place of the same number of squares. To make the shape appear to move, in the subsequent frame each target-stimulus reverted to square while the next square changed to circle, following a specific direction. The noise consisted of circle positioned randomly in the space, irrespectively to their previous position. In the MC test the target-stimuli moved coherently on a black background and the noise was obtained by stimuli moving in a Brownian manner. The subjects had to identify the directions of the coherent motion in both tests. The accuracy was evaluated for each condition. ANOVA showed a significant global effect of light condition, evidencing disrupted performances in rod-dominated vision, significant differences between the types of stimuli (lower scores in MFF as compared to MC) and a significant interaction stimuli type by light condition. In conclusion, the results confirm that in scotopic light levels motion perception is not significantly altered using MC, while it is degraded in higher order motion stimuli, such as MFF.

23.4113 **Typical development of Motion perception and Form discrimination abilities in children** Luca Mandolesi[1](luca.mandolesi2@unibo.it), Kerstin Hellgren[2], Sara Giovagnoli[1], Tony Pansell[2], Mariagrazia Benassi[1]; [1]Department of Psychology, University of Bologna, [2]Department of Clinical Neuroscience, Karolinska Institutet

Visual functions have been widely investigated in patients with developmental disorders. This study aims to analyze the development of dorsal and ventral visual function in children with typical development, measured as motion and form discrimination abilities. A sample of 304 children (age: 4-12 years; 154 males) participated in the experiment. Non-verbal intelligence (Raven's matrices), visual acuity (Lea test), motion perception (motion coherence test-MCT) and form recognition (form coherence test-FCT) were assessed. The MCT consists of 150 white dots on a black background moving coherently at a constant velocity in one of the eight directions (signal) or in a Brownian manner (noise). The task was to recognize the direction of the signal dots. The FCT consists of white dots (signal) composing one of eight possible forms through spatial alignment of the dots, the noise was created by non-aligned dots distorting the form. The task was to recognize the form. Difficulty was increased by reducing the dot coherence (signal/noise) from 100% (no noise) to 36% in five levels. MANOVA showed a significant increment of motion and form perception accuracy with age, steeper for form as compared to motion recognition. Both functions are influenced by noise but motion discrimination seemed to be less affected. While noise had a stronger effect on the younger children in the FCT (worse performance with noise in the youngest) no such age effect was found in MCT. Motion and form perception are related to general intelligence at different ages as well as to the visual acuity. These results confirm the slowness in development of dorsal function as compared to ventral function. Visuo-spatial attention, general intelligence and visual acuity mediate the visual functionality development.

Saturday Afternoon Talks

Attention: Models and mechanisms

Saturday, May 14, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Joseph MacInnes

24.11, *2:30 pm* **Applying Impressionist Painterly Techniques to Data Visualization** Pavel Kozik[1](pavelkozik@psych.ubc.ca), Laura Tateosian[2], Christopher Healey[2], James Enns[1]; [1]1Department of Psychology, University of British Columbia, Vancouver, Canada, [2]2Department of Computer Science, North Carolina State University, Raleigh, United States

An important task of science is to communicate complex data to peers and the public. Here we ask whether harnessing the painterly techniques of impressionist-era painters is beneficial. In two experiments, participants viewed weather maps from the International Panel of Climate Change that were rendered using either an industry-standard technique (glyphs) or one of three styles inspired from impressionist masters. The glyph technique used rectangular glyphs that vary properties of color and texture (e.g. hue, saturation and size) to represent corresponding data values. For the impressionist styles, regions of maximum contrast in the underlying data were rendered using brushstroke algorithms to emphasize interpretational complexity (two distinct layers of paint where unique regions have greater brushstroke overlap), indication and detail (unique regions are rendered with increased brushstroke thickness and density), and visual complexity (unique regions are rendered with different brushstrokes at a global level and reinforced with increased brushstroke variation at a local level). Visual complexity was expected to be more memorable and allow for more accurate information extraction because it both draws attention to distinct image regions and engages the viewer at those locations with increased brushstroke variability. In Experiment 1 thirty participants completed a new–old recognition test for which d-prime values of visual complexity and glyph were comparable, and both superior to the other styles. Experiment 2 tested the accuracy of numerosity estimation with a different group of thirty participants and here visual complexity was superior above all other styles. An exit poll completed at the end of both studies further revealed that the style participants identified as being "most liked" associated with higher performance relative those not selected. Incidental eye-tracking revealed impressionist styles elicited greater visual exploration over glyphs. These results offer a proof-of-concept that visualizations based on Impressionist brushstrokes can be memorable, functional, and engaging.

Acknowledgement: NSERC - Natural sciences and engineering council of canada

24.12, *2:45 pm* **Suppression of Covert and Overt Attentional Capture** Nicholas Gaspelin[1](ngaspelin@ucdavis.edu), Carly Leonard[1], Steven Luck[1,2]; [1]Center for Mind and Brain, University of California, Davis, [2]Department of Psychology, University of California, Davis

For over two decades, researchers have debated the nature of cognitive control in the guidance of visual attention. Stimulus-driven theories claim that salient stimuli automatically capture attention, whereas goal-driven theories propose that an individual's intentions determine whether salient stimuli capture attention. Problematically, both theories make the exact opposite prediction about when to expect capture in the real-world. To remedy this conflict, we propose a hybrid model called the signal suppression model, which claims that all stimuli automatically generate a salience signal. However, this signal can be actively suppressed by top-down attentional mechanisms. The current research provides converging evidence for the signal suppression hypothesis using two different paradigms, one that measures covert attention by means of psychophysical methods and another that measures overt attention by means of eye tracking. Both approaches showed that—under appropriate conditions (feature search mode)—the processing of a salient distractor is suppressed below the baseline of non-salient distractor objects.

Acknowledgement: National Eye Institute, National Institute of Mental Health

24.13, *3:00 pm* **Conjunction search is guided by the relative, context-dependent features of the target.** Stefanie Becker[1](s.becker@psy.uq.edu.au), Aimée Martin[1]; [1]School of Psychology, The University of Queensland, Brisbane, Australia.

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, Becker (2010) has shown that 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 tested whether Becker's relational account can be extended to explain conjunction search tasks for stimuli that differ only in a combination of two features from irrelevant nontargets. Observers had to search for a target with a combination of a particular color and size (e.g., large aqua) among 4 nontargets that shared the target color or size (e.g., large green, medium aqua). To test whether attention would be tuned to the exact target features, the exaggerated target features or the target-nontarget relationships (e.g., bluer, larger), we presented an irrelevant distractor prior to the target display (conjunction cue), that was embedded in a context of three other cues that shared the cue's features (cue context). Behavioral and EEG measurements demonstrated that capture by the conjunction cue depended only on whether the cue's relative color (to the cue context) matched or mismatched the target's relative attributes, and was entirely independent on whether it had the same or a different color or size as the target. Conjunction cues whose cue-context relationship matched the target-nontarget relationship captured even when the conjunction cue was identical to the nontargets. These results invalidate current feature-based theories of attention and provide strong support for the relational account, that attention is biased towards the relative attributes of the target.

Acknowledgement: ARC Future Fellowship and University of Queensland Foundation Research Excellence Award

24.14, *3:15 pm* **Evidence for successful transfer of information between the hemifields during focal, but not divided attention** Roger Strong[1](rstrong@fas.harvard.edu), George Alvarez[1]; [1]Department of Psychology, Harvard University

Tracking multiple objects with attention is easier if the objects are divided across the visual hemifields (e.g., one on in left hemifield, one in the right hemifield), as if each hemifield has a separate spotlight of attention (Alvarez & Cavanagh, 2005). If the two hemifields have separate tracking mechanisms, then it should be difficult to track targets that cross between the hemifields — a common occurrence for tracked objects encountered in everyday life. To test this possibility, observers saw pairs of identical black dots orbiting around a common point. There were always two orbiting pairs in diagonally opposite quadrants (e.g., one pair in the top-left, and one pair in the bottom-right). At the start of each trial, one dot within each pair flashed to identify it as a target to be tracked. Halfway through each trial, the target-distractor pairs simultaneously shifted vertically to a new quadrant within the same hemifield (within-hemifield movement), or horizontally to a new quadrant in the opposite hemifield (between-hemifield movement). Observers were better at identifying target dots following within-hemifield movement (M=77.2%, SD=12.1%) than following between-hemifield movement (M=66.7%, SD=13.4%; $t(15)=3.9$, $p=.001$). This difference was not attributable to difficulty tracking near the vertical midline separating the two hemifields (Experiment 2). Although a cost for between-hemifield movement was found when targets were presented to both hemifields, no cost was found when observers were required to track only a single target that moved between hemifields, even when controlling for task difficulty (Experiment 3). Together, these results suggest that hemifield-specific mechanisms struggle to transfer information when each is engaged with tracking its own target, but that these same mechanisms closely coordinate with one another when only a single target must be transferred. This coordination allows the successful representation of dynamic stimuli moving between the visual hemifields.

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24.15, *3:30 pm* **Temporal Onset Diffusion Model for spatial attention** Joseph MacInnes[1](jmacinnes@hse.ru); [1]Higher School of Economics, department of psychology

See page 3 for Abstract Numbering System

Cuing a location in space produces a short lived advantage in reaction time to targets at that location. Multiple diffusion models are presented for saccadic and manual reaction time for spatial cuing experiments with random CTOA and probe locations. Diffusion models can generate accurate distributions of reaction time data by modelling a response as a build-up of evidence towards a response threshold (Ratcliffe, 2008). An adapted diffusion model is presented which allows for spatiotemporal events to trigger changes in signal strength over time. One of the strengths of diffusion models is the ability to match model parameters with experimental manipulations to discover the potential underlying mechanisms of the decision process (Ludwig et al, 2009). Diffusion Models which allow temporal onsets have added potential to implement theories of attention which rely on sequential events and internal feedback mechanisms. Data from two experiments are presented with this model: pre and post cue effects thought to be caused feedback mechanisms and perceptual merging (Krueger et al, 2014); and new data on the transition timing of facilitation and Inhibition of Return.

24.16, *3:45 pm* **A Computational Biased Competition Model of Visual Attention using Deep Neural Networks** Hossein Adeli[1](hossein.adelijelodar@stonybrook.edu), Gregory Zelinsky[1,2]; [1]Department of Psychology, [2]Department of Computer Science

“Biased competition theory” proposes that visual attention reflects competition among bottom-up signals at multiple stages of processing, and the biasing of this competition by top-down spatial, feature, and object-based modulations. Our work advances this theory in two key respects: by instantiating it as a computational model having an image-based “front-end”, thereby enabling predictions using real-world stimuli, and by using an 8-layer deep neural network to model ventral pathway visual processing. A categorical cue (object name) activates a specific frontal node (goal state; layer 8), which feeds activation back to modulate Inferior Temporal (IT; layers 7-6) and V4 (layer 5) using the same feedforward weights trained for object classification. This feedback is multiplied by the feedforward bottom-up activation, biasing the competition in favor of target features (feature-based attention). Reentrant connectivity between V4 and FEF selects a spatial location (spatial attention), causing the selective routing (attentional gating) of object information at that location. This routing constricts receptive fields of IT units to a single object and makes possible its verification as a member of the cued category. Biased retinotopic V4 activation and spatial biases from FEF and LIP (maintaining an Inhibition-of-Return map) project to the superior colliculus, where they integrate to create a priority map used to direct movements of overt attention. We tested our model using a categorical search task (15 subjects, 25 categories of common objects, 5 set sizes), where it predicted almost perfectly the number of fixations and saccade-distance travelled to search targets (attentional guidance) as well as recognition accuracy following target fixation. In conclusion, this biologically-plausible biased competition model, built using a deep neural network, not only can predict attention and recognition performance in the context of categorical search, it can also serve as a computational framework for testing predictions of brain activity throughout the cortico-collicular attention circuit.

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24.17, *4:00 pm* **The self survives extinction: Self-association biases attention in patients with visual extinction** Glyn Humphreys[1](glyn.humphreys@psy.ox.ac.uk), Jie Sui[1]; [1]Department of Experimental Psychology, Oxford University, Oxford, UK

People show biases to self-related information on a range of tasks. One key controversial question is whether self-related information is processed without awareness, which then determines what is attended. We examined this using patients showing visual extinction. Extinction patients can respond to a single stimulus on their affected side but are unaware of the same item if another stimulus appears at the same time on the unimpaired side. This dramatic loss of awareness can be affected by the properties of stimuli, providing an index of which stimulus properties can be processed without awareness. We had patients associate different shapes with themselves or their best friend and then had them identify single or pairs of shapes. When the self-shape was paired with the shape for the friend, patients showed extinction of the friend shape and reported the self shape even when it was on the affected side and the friend on the unimpaired side. The data provide novel evidence that self-relatedness can be computed without awareness and then affects which region of space patients attend to. Self-relatedness can shift stimuli from unconscious to a conscious state, consistent with self-reference providing a fundamental aspect of cognition.

Acknowledgement: European Research Council, Wellcome Trust

3D Perception

Saturday, May 14, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Jennie Read

24.21, *2:30 pm* **How Natural Distributions of Blur Affect 3D Percepts** Martin Banks[1](martybanks@berkeley.edu), William Sprague[1], Emily Cooper[2], Sylvain Reissier[1]; [1]Vision Science Program, School of Optometry, UC Berkeley, [2]Department of Psychology, Dartmouth College

We asked whether natural distributions of blur in different parts of the visual field influence 3D percepts. With a mobile eye-and-scene tracker, we measured distances in the scene, fixations, and pupil diameters as people engaged in everyday activities. From those measurements, we calculated point-spread functions for all positions in the central 20 degrees of the visual field across all frames. The distributions of blur varied from task to task, but a weighted combination across tasks revealed consistent patterns. As shown in Figure 1A, there is a consistent vertical gradient of signed blur: Positions below the fovea are generally blurred because most scene points are nearer than fixation (orange); points above the fovea are also blurred because most scene points are farther than fixation (purple). There is no consistent horizontal gradient. These data manifest the prior distribution of blur across the visual field. We next asked whether this distribution affects 3D percepts. We presented random textures with different blur gradients (Figure 1B). When no gradient was present (i.e., the texture was equally sharp everywhere), subjects perceived a frontoparallel plane. When a vertical blur gradient was present, subjects generally perceived a surface slanted top-back even though that stimulus is also geometrically consistent with top-forward slant and with convex and concave wedges. When a horizontal gradient was present, subjects perceived surfaces slanted left-side forward and right-side forward with equally probability. These data are quite consistent with the natural distributions of blur across the visual field. They show that humans use this prior blur distribution to infer 3D shape.

Acknowledgement: NSF

24.22, *2:45 pm* **Local Estimation of Global Surface Orientation from Texture and Disparity** Wilson Geisler[1](w.geisler@utexas.edu); [1]University of Texas at Austin

The visual system has a remarkable ability to encode the geometry of the 3D environment from the pair of 2D images captured by the eyes. It does so by making measurements of local image properties, including texture and binocular disparity, and then combining those measurements across the visual field into a coherent 3D representation. Although much is known about how the visual system encodes local texture and disparity, less is known about how those properties are combined across space, especially in the creation of 3D representations. This presentation will describe how to optimally estimate the orientation and distance of locally-planar surfaces from texture cues and from disparity cues so that a coherent global 3D representation is (in effect) created automatically. The approach is based on exact closed-form expressions for the coordinate transformations between image patches within an eye and across the eyes, given a locally-planar surface of arbitrary slant, tilt and distance. In this framework, slant, tilt and distance are specified in a global coordinate frame aligned with the optic axis of the eye(s). It turns out that these globally-defined surface properties can be estimated at any image point by local image matching, potentially simplifying 3D perceptual grouping. For example, in binocular matching, all image points that are in the ground plane will return the same slant, tilt and distance (in the global coordinate frame). Thus, the grouping of image locations that belong to the ground plane becomes as simple as grouping image locations that have a similar color. The same result holds for texture, except only globally-defined slant and tilt are returned. The efficacy of the approach is demonstrated in simulations. Perhaps the brain simplifies the circuitry needed for 3D perceptual grouping by making local measurements in a global coordinate system.

Acknowledgement: NIH grant EY11747

24.23, *3:00 pm* **Depth perception and segmentation: A common dependence on texture sparseness and local phase structure** Athena Buckthought[1](athenabuck1@gmail.com), Curtis Baker[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

To perceive the 3D layout of a scene, the visual system must parse the image into different objects (segmentation) and determine their relative distances (depth ordering). Either stereopsis or relative image motion resulting from movement of the observer (motion parallax) could serve as

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perceptual cues for these tasks, but very little is known about the effects of image statistics in either of these modalities. Here we examine the influence of specific higher-order texture statistics on depth and segmentation, in motion parallax and stereopsis, using naturalistic synthetic micropattern textures. The textures consisted of edgelet micropatterns at different densities, which could be phase-scrambled either locally or globally (Zavitz & Baker, 2013), thus allowing us to manipulate sparseness, global phase structure, and local phase alignments. The textures were displayed in a circular aperture (28 deg diameter). For motion parallax, relative texture motion (shearing) was synchronized to horizontal head movement with low spatial frequency (0.05 cpd) horizontal square wave modulations. Four observers performed a 2AFC depth ordering task, in which they reported which modulation half-cycle of the texture appeared in front of the other. Binocular vision was assessed by a similar depth ordering task of disparity-defined surfaces, with the same display and matched stimulus parameter settings. The observers also carried out a segmentation task in which they discriminated the orientation of a square wave modulated boundary in depth, in motion parallax or stereopsis. Surprisingly, we obtained a strikingly similar pattern of results for depth ordering and segmentation, and both motion parallax and stereopsis: (1) randomizing all structure by globally phase-scrambling the texture improved performance, (2) decreasing sparseness also improved performance and (3) removing local phase alignments had little or no effect. These results provide evidence for a commonality of early texture processing mechanisms for depth and segmentation in both motion parallax and stereopsis.

Acknowledgement: This work was funded by a grant from the Natural Sciences and Engineering Research Council of Canada RGPIN/1998-2012 to C.L. Baker.

24.24, *3:15 pm* **Depth discrimination from occlusions in 3D clutter scenes** Michael Langer[1](langer@cim.mcgill.ca), Haomin Zheng[1], Shayan Rezvankhah[1]; [1]School of Computer Science, McGill University

Objects such as trees, shrubs, and tall grass typically consist of thousands of small surfaces that are distributed randomly over a 3D volume. Despite the common occurrence of such 3D clutter in natural scenes, relatively little is known about how well humans can perceive depths of surfaces within such 3D clutter. Previous studies have concentrated on motion parallax and binocular disparity cues and have asked questions such as how many discrete depth planes can be perceived, and what is the depth-to-width ratio. However, these studies are incomplete because they have ignored occlusions which are omnipresent in such scenes. Here we present a depth discrimination experiment that examines occlusion cues directly. The task is to discriminate the depths of two red target surfaces in a 3D field of random gray distractors. The experiment uses an Oculus Rift DK2 display which allows us to control motion parallax and binocular disparity cues. The clutter itself provides two occlusion-based depth cues. The first is a 'visibility cue', namely, the target that is less visible is more likely to be deeper within the clutter [Langer and Mannan, JOSA 2012]. The second is a 'context cue', namely the target with the deepest occluder is itself more likely to be deeper. We define scene classes with all four combinations of visibility and occlusion cues and use staircases to measure depth discrimination thresholds. Our results show that observers use both visibility and context cues to perform the task, even when stereo and motion parallax cues are also present. To our knowledge, this is the first experiment to examine depth from occlusions in 3D clutter and to identify the important role played by visibility and context cues in solving this natural problem.

Acknowledgement: FQRNT

24.25, *3:30 pm* **Integration of perspective and disparity cues in the neural representation of 3D object orientation** Ari Rosenberg[1](ari.rosenberg@wisc.edu), Dora Angelaki[2]; [1]Neuroscience, University of Wisconsin-Madison, [2]Neuroscience, Baylor College of Medicine

Creating three-dimensional (3D) visual representations of the environment from two-dimensional (2D) retinal images is a complex but fundamental problem the brain solves to support perception and action. Here we present results from electrophysiological experiments conducted in the caudal intraparietal area (CIP) of the macaque monkey to elucidate the role of perspective and binocular disparity cues in the neural representation of 3D object orientation. Using planar surface stimuli, these experiments reveal that individual CIP neurons are selectively tuned for both slant (rotation about an axis perpendicular to the line-of-sight) and tilt (rotation about an axis parallel to the line-of-sight), two parameters defining 3D orientation. Across the population of recorded neurons, the distribution of preferred orientations was statistically indistinguishable from uniform. This property may be beneficial for guiding interactions with objects, consistent with CIP's projection to areas implicated in affordance-based actions such as grasping. Previous theoretical and psychophysical studies show that the relative reliability of perspective (compared to disparity) cues increases with slant. Since accurate 3D perception requires that these cues be integrated according to their reliabilities, the contributions of perspective and disparity cues to the responses of CIP neurons were evaluated. The contribution of each cue was dissociated by measuring planar slant tuning curves using mixed-cue (both perspective and disparity cues, either congruent or conflicting) and cue-isolated (perspective or disparity) stimuli. We find that perspective contributes more to the responses of CIP neurons preferring larger slants, mirroring the slant-dependent reliability of perspective cues. Moreover, some neurons that are sensitive to both cues when tuning is assessed with cue-isolated stimuli are found to disregard one of the cues when they are presented together, but in conflict. These findings suggest that perspective and disparity cues are weighted according to their slant-dependent reliabilities in area CIP to create robust 3D representations of object orientation.

Acknowledgement: DC014305

24.26, *3:45 pm* **Coupled computations of defocus, 3D shape, and illumination direction** Scott Mooney[1](scott.mooney@sydney.edu.au), Barton Anderson[1]; [1]School of Psychology, University of Sydney

Image defocus has been studied extensively as a depth cue, but little is known about how the visual system disentangles image defocus from environmental sources such as diffuse surface shading. Here, we show that the perception of defocus can arise even when viewing fully focused, smoothly shaded bumpy surfaces. We further show that introducing sharp contours adjacent to the shaded surface can completely eliminate this percept of defocus, but only if the contours are perceived as self-occluding edges attached to the gradients. In Experiment 1, we generated sharp-edged 'masks' by taking level cuts of a smoothly shaded bumpy terrain and compared the perception of blur and 3D shape of the remaining gradients to images in which the level cut masks were rotated 180 degrees. The geometrically correct level cuts induced a dramatic decrease in perceived defocus and highly reliable 3D shape measurements, whereas the shading gradients bordered by rotated masks exhibited little change in perceived defocus and elicited poor measurements of 3D shape. In Experiment 2, we presented only a narrow strip of the gradients immediately adjacent to the mask edges to determine what led to the dramatic differences in 3D shape and defocus observed in Experiment 1. Our results show that the reduction in defocus and enhancement of 3D shape generated by the 'attached' contours of the level cut masks arises from the perception of surface relief and consistent light field direction that can be derived using information from these contour-adjacent shading strips alone; coherent percepts of 3D shape and illumination direction are experienced only with the strips adjacent to the unrotated masks. Our results demonstrate that the computation of defocus in images of shaded surfaces is intrinsically coupled to the information about 3D shape and illumination that can (or cannot) be derived from photogeometric constraints along sharp contours.

24.27, *4:00 pm* **Recovering stereo vision by squashing virtual bugs in a VR environment.** Dennis Levi[1](dlevi@berkeley.edu), Indu Vedamurthy[2], David Knill[2], Jian Ding[1], Oh-Sang Kwon [3], Daphne Bavelier[1]; [1]School of Optometry and Helen Wills Neuroscience Institute, University of California, Berkeley, [2]Department of Brain & Cognitive Sciences, University of Rochester, [3]School of Design & Human Engineering, UNIST, South Korea

Stereopsis is the rich impression of three-dimensionality, based on binocular disparity—the differences between the two retinal images of the same world. However, a substantial proportion of the population is stereo deficient, and relies mostly on monocular cues to judge the relative depth or distance of objects in the environment. In this study we trained eleven adults who were stereo blind or stereo deficient due to strabismus and/or amblyopia in a natural visuo-motor task – a "bug squashing" game - in a virtual reality (VR) environment. The subjects' task was to squash a virtual dichoptic bug on a slanted surface, by hitting it with a cylinder. The slant of the surface was determined by purely stereoscopic cues (stereo-cue trials), monocular texture as well as stereoscopic cues (cue-consistent trials), and conflicting monocular and stereo cues (cue-conflict trials). A motion-capture system tracked the 3D position and orientation of the cylinder. We determined the relative weight that participants gave to stereo cues by regressing the slant of the cylinder just prior to contact with the surface against the slant depicted by the texture and the slant depicted by stereoscopic disparities [Knill, 2005]. Following 35 training sessions of about 1hour, eight of the eleven participants (two anisometropic and six strabismic) showed greater reliance on stereoscopic cues, and improved stereo-acuity. Importantly, the training-induced changes in relative stereo weights were significant predictors of the improvements in stereoacuity. Additionally, all but one subject

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showed reduced suppression, and three also showed improved visual acuity. We conclude that some adults deprived of normal binocular vision and insensitive to the disparity information can, with experience in bug squashing, recover access to more reliable disparity information. Importantly, our bug squashing training involves integrating not just multiple visual cues, but also the rich information from tactile and kinesthetic feedback.

Acknowledgement: NEI grant RO1EY020976

Development: Typical

Saturday, May 14, 5:15 - 6:45 pm
Talk Session, Talk Room 1
Moderator: Lisa Scott

25.11, *5:15 pm* Tract-Based Spatial Statistics from Diffusion-Weighted Mri Reveal Specific White Matter Correlates of Global Motion Sensitivity in Typically Developing Children Oliver Braddick[1](oliver.braddick@psy.ox.ac.uk), Janette Atkinson[2], Akshoomoff Natacha[3,4], Erik Newman[3], Lauren Curley[3,8], Anders Dale[5,7], Terry Jernigan[3,4,6,8]; [1]Experimental Psychology, Oxford University, [2]Div Psychology & Language Sciences, University College London, [3]Center for Human Development, University of California San Diego (UCSD), [4]Psychiatry, UCSD, [5]Radiology, UCSD, [6]Psychiatry, UCSD, [7]Neurosciences, UCSD, [8]Cognitive Science, UCSD

Impaired sensitivity to global motion, but not to global form, has been found as a signature in a range of neurodevelopmental disorders, often associated with spatial and attention deficits and poor mathematical skills Previously we reported (Atkinson et al, VSS 2014) individual differences in global motion in typically developing children, high sensitivity being associated with a relatively enlarged surface area of the parietal lobe (especially around the intraparietal sulcus) and reduced occipital area. Here we explore whether global motion sensitivity is also associated with organization in white matter fibre tracts. We analysed fractional anisotropy (FA) within major fibre tracts defined by tract-based spatial statistics (TBSS) in 125 typically developing children from the PLING study (Pediatric Longitudinal Imaging Neurocognition and Genetics). The superior longitudinal fasciculus (SLF) was treated as the main candidate tract, given its connections to parietal areas previously associated with global motion performance. We found higher global motion sensitivity was related to asymmetry in the SLF, with higher FA in the right SLF showing a positive association (p=0.003), and the left a negative association (p=0.02). This relation was not found for overall FA or for other specific tracts, and was not found for global form. In contrast we found that the parietal surface area expansion associated with motion performance was stronger in the left than in the right hemisphere. We conclude that (a) developmental variation in global motion sensitivity is linked to local white matter organization in SLF, as well as to regional differences in parietal area ; (b) a complex pattern of hemispheric asymmetry in both fibre tracts and cortical area is associated with the phenotype of high global motion sensitivity. These finding provide pointers for the neuroanatomical investigation of the visual correlates of neurodevelopmental disabilities.

Acknowledgement: NIH R01HD061414 and RC2DA029475

25.12, *5:30 pm* The Stability of Fixation in Depth in 5-10-Week-Old Infants Eric Seemiller[1](eric.seemiller@gmail.com), Nicholas Port[1], T. Candy[1]; [1]School of Optometry, Indiana University

Introduction Though studies have found that instability in horizontal and vertical eye position may limit visual processes in strabismic and amblyopic observers (e.g., Subramian, et al. 2013), little attention has been paid to fixation in depth. Could instability in binocular alignment be a significant barrier to disparity processing in young infants? In this study, observers were presented with random noise while variation in their horizontal, vertical and disconjugate eye position over time was determined. Methods Adults (n=9) and infants (n=11) aged between 5 and 10 weeks viewed dichoptic, random noise (60° by 44°) from a viewing distance of 65 cm. Each noise pixel subtended 6° vertically by 3° horizontally, and updated at 3 Hz to prevent prolonged binocular fixation on a feature. The only information for alignment in depth came from the zero-disparity binocular cue. Saccades > 2° were removed and intersaccade intervals were normalized. Five-second epochs of cooperative fixation within the central 10 degrees of the stimulus were analyzed. Results & Discussion For adults, the standard deviation (SD) of horizontal vergence position was smaller during binocular viewing (mean +/- SD = 0.197 +/- 0.077°) than monocular viewing (0.259 +/- 0.216°; paired t-test, p =0.036). Infants (0.391 +/- 0.533°) had larger standard deviations in binocular viewing than adults by a factor of two. Interestingly, vertical vergence position in infants (0.232 +/- 0.33°) was not significantly different from adults (0.279 +/- 0.251°). Longitudinal data from four infants revealed that SD in horizontal vergence decreased by an average of 0.345 +/- 0.319° between 5 and 10 weeks. These data suggest immaturity in horizontal vergence that may not be present in vertical vergence between 5 and 10 weeks. Implications for normal and abnormal binocular development will be discussed.

Acknowledgement: R01 EY014460(TRC), P30 EY019008

25.13, *5:45 pm* Category-sensitive visual regions in human infants Ben Deen[1](bdeen@mit.edu), Hilary Richardson[1], Daniel Dilks[2], Atsushi Takahashi[1], Boris Keil[3], Lawrence Wald[3], Nancy Kanwisher[1], Rebecca Saxe[1]; [1]Department of Brain and Cognitive Sciences and McGovern Institute, Massachusetts Institute of Technology, [2]Department of Psychology, Emory University, [3]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital

The ventral visual pathway in humans has a stereotyped functional organization, in which regions selective for specific visual categories are found in approximately the same location in virtually every normal adult. How does this systematic structure arise in development? Are category-sensitive regions largely innately specified and present from early in development, or do they develop gradually, after extensive visual experience with specific categories? Here we develop and apply methods for fMRI in awake infants to address this question. We scanned 2-8-month-old infants (N = 17, 63 total scan sessions) while viewing infant-friendly videos depicting faces, bodies, inanimate objects, natural scenes and scrambled scenes. Several novel methodological approaches were employed, including infant-sized head coils, quiet pulse sequences, and a combination of novel and extant data analysis techniques for reducing the impact of head motion. In infants with enough low-motion data (n=9 infants), we observed face- and scene-preferring in the same locations as the corresponding category-sensitive extrastriate regions in adults. These response profiles were replicated in independent data, and in two sets of movie stimuli. At least in some cases, responses in these regions were better explained by high-level category preferences than by low-level stimulus features such as spatial frequency and rectilinearity. However, strongly selective regions, preferring one visual category over all others, were not observed in infants, in contrast to adults. These results demonstrate that the location of multiple category-sensitive regions is already staked out in cortex within a few months after birth, but strong adult-like category selectivity does not emerge until later in development.

25.14, *6:00 pm* Connectivity precedes function in the development of the visual word form area Nancy Kanwisher[1](ngk@mit.edu), David Osher[2], Elizabeth Norton[1], Deanna Youssoufian[3], Sara Beach[1], Jenelle Feather[1], John Gabrieli[1], Zeynep Saygin[1]; [1]Dept. of Brain & Cognitive Sciences, Massachusetts Institute of Technology, [2]Dept. of Psychological & Brain Sciences, Boston University, [3]Dept. of Biological Sciences, Barnard College, Columbia University

What determines the cortical location where a given functionally specific region will arise in development? Here we test the hypothesis that functionally specific regions develop in their characteristic locations because of pre-existing differences in the extrinsic connectivity of that region to the rest of the brain. We exploit the Visual Word Form Area (VWFA) as a test case, because it arises only after children learn to read. We scanned children with diffusion and functional imaging at age five, before they learned to read, and at age 8, after they learned to read. We find the VWFA develops functionally in this interval and that its location in a particular child at age 8 can be predicted from that child's connectivity fingerprints (but not functional responses) at age 5. These results suggest that early connectivity instructs the functional development of the VWFA, possibly reflecting a general mechanism of cortical development.

25.15, *6:15 pm* The development of population receptive field size in visual cortex during childhood Tessa Dekker[1,2](tes.m.dekker@gmail.com), Samuel Schwarzkopf[1], Aisha McLean[2], Catherine Manning[3], John Greenwood[1], Marko Nardini[4], Martin Sereno[1]; [1]Psychology and Language Sciences, University College London, [2]Department of Visual Neuroscience, Institute of Ophthalmology, University College London, [3]Department of Experimental Pscycholgy, Medical Sciences, Oxford University, [4]Department of Psychology, Durham University

Whilst dramatic changes in visual ability occur during the first year of life, many aspects of vision continue to develop substantially during childhood, with some only maturing in the early teens. For example, visuospatial processing during motion averaging and crowding tasks still improves after

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age 6 years (Manning, Dakin, Tibber & Pellicano, 2014; Greenwood et al., 2012; our own unpublished replication of these findings). We explored how changes in visual skills might be linked to visuospatial selectivity in the developing cortex, by adapting recently developed MRI and population receptive field (pRF) mapping methods (Dumoulin & Wandell, 2008) for children. We fitted a pRF model to fMRI signals measured while 6- to 12-year-old children (N=38) viewed an expanding ring and rotating wedge traversing the visual field. In a preliminary analysis with a subset of 18 children, we estimated pRF size and location for each voxel. Location estimates were used to generate polar angle maps to identify retinotopic regions of interest (V1-V3) in visual cortex. We found that as in adults, pRF size increased as a function of eccentricity, and from V1-3. In addition, a bootstrapping analysis comparing younger children (6-8 years, N=7) to older children (9-12 years, N=11), revealed a general increase in pRF size with age in V1 and V2, and peripherally in V3 ($p< 0.05$, Bonferroni-corrected). This is unlikely to be explained by confounding head-movements or by eye-movements away from the central fixation task, as these would predict larger pRF sizes in younger children. Thus, changes in low-level functions of the visual cortex may contribute to improvements in visual ability in late childhood. This work demonstrates for the first time that pRF estimation methods can be used successfully with young children, paving the way for in-vivo investigation of visual cortex organization and processing resolution during normal and abnormal visual development.

Acknowledgement: This work was funded by the Swire Trust, a Moorfields Eye Hospital Special Trustees Project Support Grant, UK ESRC grant RES-061-25-0523, the NIHR Biomedical Research Centre at Moorfields Eye Hospital and the UCL Institute of Ophthalmology

25.16, *6:30 pm* **Gender differences in visual perception** Albulena Shaqiri[1](albulena.shaqiri@epfl.ch), Andreas Brand[2], Maya Roinishvili[3,4], Marina Kunchulia[3,5], Guillaume Sierro[6], Julie Willemin[6], Eka Chkonia[3,7], Luisa Iannantuoni[6], Karin Pilz[8], Christine Mohr[6], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Institute for Psychology and Cognition Research, University Bremen, Bremen, Germany, [3]Institute of Cognitive Neurosciences, Agricultural University of Georgia, Tbilisi, Georgia, [4]Vision Research Laboratory, Beritashvili Centre of Experimental Biomedicine, Tbilisi, Georgia, [5]Laboratory of Vision Physiology, Beritashvili Center of Experimental Biomedicine, Tbilisi, Georgia, [6]Institute of Psychology, Faculty of Social and Political Sciences, Bâtiment Geopolis, Quartier Mouline, Lausanne, Switzerland, [7]Department of Psychiatry, Tbilisi State Medical University, Tbilisi, Georgia, [8]School of Psychology, University of Aberdeen, Scotland, UK

Gender differences are well established in cognition and somato-sensation, but there are almost no studies on gender differences in visual perception. In vision experiments, sample size of participants is often small because effect sizes are large. However, small samples are not well suited to test for gender differences. Here, we pooled data from 4 studies resulting in 1091 participants ranging in age from 14 to 90 years. We tested participants' performance in visual and vernier acuity, visual backward masking and the Wisconsin Card Sorting Test. We found no gender differences in any of the four tests for younger participants (n=431; 14-30 years old). Even in a subgroup of schizophrenia patients (n=291), we did not find gender differences, but large performance deficits in patients compared to controls. For middle-aged participants (n=185; 31-59 years old), men performed significantly better than women in all perceptual tests, even when we controlled for age. We also found better performance of men compared to women in vernier duration in older participants (n=183; 60-90 years old) and trends in the same direction for the other tests. Hence, it may be that women's performance deteriorates with age more strongly than men's performance. We did not find any difference in the Wisconsin card sorting test, indicating no gender differences for executive functions.

Face Perception: Emotion and social

Saturday, May 14, 5:15 - 6:45 pm

Talk Session, Talk Room 2

Moderator: Ipek Oruc

25.21, *5:15 pm* **Efficiency and equivalent internal noise for own- and other-race face recognition suggest qualitatively similar processing** Ipek Oruc[1](ipor@mail.ubc.ca), Fakhri Shafai[1,2]; [1]Ophthalmology and Visual Sciences, University of British Columbia, [2]Graduate program in Neuroscience, University of British Columbia

Identification of faces of a non-native race is drastically impaired compared to performance with own-race faces (Hancock & Rhodes, 2008; Meissner & Brigham, 2001). It is known that differential experience brings about this effect yet it is not clear how experience, or the lack thereof, with a particular race impacts neural processing of faces. It has been suggested that unlike own-race faces, other-race faces do not benefit from expert holistic processes but are recognized via general-purpose processes in a piece-meal fashion similar to other, non-face, visual forms (Rossion, 2008; Tanaka, Kiefer, & Bukach, 2004). Alternatively, the difference may stem from quantitative, rather than qualitative, changes in processing. Under this hypothesis, the neural computation that leads to recognition itself is the same in both own- and other-race faces; but in the case of other-race faces the input is noisier due to reduced experience. In order to discriminate between these alternative models we measured contrast recognition thresholds in a 5AFC paradigm for three classes of stimuli: a) own-race faces b) other-race faces, and c) houses. Contrast thresholds were measured in white noise and no-noise conditions. High-noise efficiency and equivalent internal noise for the human observers across the three stimulus conditions were computed relative to an ideal observer that performed the same tasks. We predicted lower efficiencies for houses, which are recognized via general-purpose processes, compared to own-race faces, which are recognized via expert holistic processes. We found both own-race and other-race efficiencies to be significantly higher than that for houses. Efficiencies did not differ between the two face conditions but equivalent input noise was higher for other-race faces. These results do not support the idea of distinct processing styles for own-vs. other-race faces. Instead, they suggest qualitatively similar processing regardless of race.

Acknowledgement: This work was supported by grants from the Autism Research Training Program, CIHR (FS) and Natural Sciences and Engineering Research Council of Canada Discovery Program RGPIN 402654-11 (IO).

25.22, *5:30 pm* **Interactions between dynamic facial features are phase-dependent** Ben Brown[1](ben.brown.13@ucl.ac.uk), Alan Johnston[1]; [1]School of Psychology, University of Nottingham

Dynamic expressions are comprised of spatially disparate features moving in temporally coordinated ways. Cook, Aichelburg & Johnston (Psychological Science, 2015) reported that oscillatory mouth movement causes concurrent eye-blinks to appear slower (suggesting interdependent processing of features), but whether it also impairs judgement of dynamic feature movement (i.e. discrimination performance) is unclear. Cook et al.'s illusion was specific to certain eye-mouth phase relationships, so here we asked whether performance similarly depends on relative phase of feature movement. Our stimuli contained sinusoidal eyebrow (raised-lowered) and mouth movement (opening-closing). Using a 2AFC design, we measured detectability of misaligned eyebrow movement across a range of temporal offsets relative to the mouth. Subjects viewed two animated facial avatars either side of fixation for 3 seconds. The eyebrows and mouth oscillated at 1.5Hz. The standard's eyebrows moved in phase, while the comparison's were misaligned by 12.5 degrees of phase angle. Subjects judged which face's eyebrows were misaligned. Eyebrow oscillation could lead mouths by 0° (eyebrows raised when mouth open) to 315° (mouth open before eyebrows raised) in increments of 45°, randomised across trials. Faces could be upright or inverted, in separate blocks. We tested 16 participants, and fixation was enforced using an eyetracker. Performance varied significantly as a function of eyebrow-mouth relative phase, and there was a significant interaction with face orientation. Polar phase plots show a bimodal circular distribution, with a performance advantage for upright faces when the mouth leads the eyebrows (180-315°). Collapsing over phase confirmed a significant interaction between orientation and phase domain (eyebrows ahead vs. mouth ahead). The data demonstrate a common encoding for facial features that is specific to upright faces and sensitive to the relative timing of their movement. This suggests processing of global facial motion is mediated by internal models with preferred temporal phase relationships between dynamic features.

Acknowledgement: BBSRC

25.23, *5:45 pm* **Facial Expressions of Pain and Pleasure are Highly Distinct** Chaona Chen[1](c.chen.1@research.gla.ac.uk), Carlos Crivelli [3], Oliver Garrod[2], Jose-Miguel Fernandez-Dols[3], Philippe Schyns[1,2], Rachael Jack[1,2]; [1]School of Psychology, University of Glasgow, Scotland, UK, [2]Institute of Neuroscience and Psychology, University of Glasgow, Scotland, UK, [3]Universidad Autónoma de Madrid, Madrid, Spain

As a highly social species, humans regularly exchange sophisticated social signals to support everyday life and the functioning of wider society. One of the most important aspects of social interaction is communicating negative (i.e., pain) and positive (i.e., pleasure) internal states. Although pain

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and pleasure are diametrically opposite concepts (Russell, 1980), several studies claim that facial expressions of pain and pleasure are too similar to support communication (Aviezer, Trope, & Todorov, 2012; Hughes & Nicholson, 2008) thereby questioning their function as social signals (Fernández-Dols, Carrera, & Crivelli, 2011). Here, we address this question by modelling the dynamic facial expressions that represent pain and pleasure (i.e. orgasm) in two cultures (40 Western, 40 East Asian observers) using a dynamic facial expression generator (Yu, Garrod, & Schyns, 2012) and reverse correlation (Ahumada & Lovell, 1971; see Fig S1, Panel A; see also Gill, Garrod, Jack, & Schyns, 2014; Jack, Garrod, & Schyns, 2014; Jack, Garrod, Yu, Caldara, & Schyns, 2012). In each culture, comparison of the pain and orgasm dynamic facial expression patterns show that they comprise highly distinct (i.e. decorrelated) signals that observers from each culture can easily detect (measured with d-prime). In addition, cross-cultural analyses showed that pain facial expressions are highly similar within and across cultures (see Fig S1, Panel B), supporting views of their culturally common physiological roots (e.g., the gate-control hypothesis, Melzack & Wall, 1967). In contrast, orgasm facial expressions form distinct clusters within each culture, suggesting the contribution of cultural learning and their role as evolved social signals (Baumeister & Bratslavsky, 1999; Eibl-Eibesfeldt, 1989). Together, our data challenges the common view that facial expressions of pain and pleasure are indistinct, non-diagnostic signals of extreme positive and negative emotion, and provides insights into the biological and cultural basis of facial expressions of pain and pleasure.

Acknowledgement: Economic and Social Research Council

25.24, *6:00 pm* **Visualizing the Information Content of 3D Face Memory in Individual Participants** Jiayu Zhan[1](j.zhan.1@research.gla.ac.uk), Nicola Van Rijsbergen[2], Oliver Garrod[2], Philippe Schyns[1,2]; [1]School of Psychology, University of Glasgow, Scotland, UK, G12 8QB, [2]Institute of Neuroscience and Psychology, University of Glasgow, Scotland, UK, G12 8QB

To access the identity of a face, observers match the visual representations of the input to their face memory. Here, for the first time we reveal the 3D information content of face memory applying reverse correlation to a generative space of face identity. Using 355 faces (coded on 4735 3D vertices and 800 * 600 texture pixels) and a General Linear Model (GLM) we extracted the linear factors of ethnicity, gender and age (and their interactions). We then performed a Principal Components Analysis on the GLM residuals to extract the components of identity variance the GLM did not capture. The GLM recodes each original face as a linear combination of components of ethnicity, gender and age (and their interactions) plus a linear weighting of the 355 Principal Components of residual identity. We generated random identities with the GLM by assigning random weights to the 355 Principal Component of residual identity (S1-A). On each trial, participants (N = 10) saw 6 random identities simultaneously presented. Participants selected the random identity most similar to two familiar identities (not included in the 355 faces used to build the generative GLM) and they rated its similarity with the familiar identities (S1-A). The experiment comprised 180 blocks of 20 trials each (90 blocks per identity randomly interleaved). For each participant and identity, we linearly regressed the 3D vertice coordinates of the chosen random faces with the participant's perceived similarity ratings (S1 for details). The resulting 'Classification 3D faces' reveal faithful 3D information content representing the memory of each familiar face (S1-B), at both a local (e.g. eye size and mouth shape) and a global scale (e.g. overall face shape). For the first time, our approach and results quantify the multivariate information content of face memory, within a framework that is straightforwardly generalizable to brain measures.

25.25, *6:15 pm* **The Intrinsic Memorability of Face Identities** Wilma Bainbridge[1](wilma@mit.edu); [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Some people in our lives stick in our memories while others are instantly forgotten. Memorability—whether a stimulus is likely to be later remembered—is found to be highly consistent for face images; people tend to remember and forget the same images. However, is memorability also intrinsic to a facial identity, generalizable across different images of a single person? 5,210 participants completed an online memory experiment testing face identity recognition over five different emotional and viewpoint transformations (neutral, happy, angry, 3/4 view, and profile view). Participants saw a stream of novel face images and indicated when they saw a repeated person, regardless of if the image was different or not. Memorability was found to be highly consistent within each image, as well as when training and testing on different images of the same person. Memorability ranking was also consistent across transformations—if a face was remembered in one image, it was also likely to be remembered in another. These results held true over both emotion expression transformations as well as viewpoint transformations. In addition, an asymmetry was found where encoding neutral (forward-facing, neutral emotion) images did not diminish memory performance, while encoding transformations did, hinting towards a prototype-based face memory representation. In whole, these results provide first evidence for an intrinsic, core memorability to a person or entity, beyond specific images.

Acknowledgement: NDSEG to W.A.B.

25.26, *6:30 pm* **Cultural Diversity in Eye Movements is Shaped by Nurture not Nature** Roberto Caldara[1](roberto.caldara@unifr.ch), Junpeng Lao[1], Anne-Raphaelle Richoz[1], Yingdi Liu[1]; [1]Department of Psychology, University of Fribourg, Switzerland

Humans adapt to their environment through a unique amalgamation of culture and biology. Historically, it has long been presumed that across cultures, all humans perceive and sample the world in a comparable manner. Recently, however, this notion has been disputed by evidence showing fundamental perceptual differences between people from Eastern and Western cultures, for high- (e.g., faces) and low-level (e.g., reflexive saccades) visual information sampling strategies. Easterners perform global/central fixations towards the nose during face recognition and exhibit a larger number of low-latency express saccades. Westerners instead spread (local) fixations across the eye and mouth regions and execute significantly fewer low-latency express saccades. Yet, whether these well-established cultural differences are related to nature or nurture remains unaddressed. To address this issue, we recorded the eye movements of sixteen South Korean adults that were adopted in Switzerland during their firsts months of life, while they performed an old/new face recognition task and visually guided saccades. South Korean Adoptees (SKA) were culturally similar to Westerners, as measured by socio-cultural scales. For face recognition, the fitting results of a Bayesian model built from previous 2D cultural fixation data, objectively showed a clear-cut overlap between the SKA and the Western oculomotor distributions. Critically, the SKA also showed significantly fewer low-latency express saccades compared to Eastern observers, a profile once again comparable to Westerners. Our data show that nurture—not nature—is responsible for cultural variations in eye movements for faces and reflexive saccades. Crucially, these findings demonstrate that the oculomotor system is plastic enough to reverse cultural determinants in visual information sampling.

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Color and Light: Adaptation and constancy

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3001 Colour constancy as a product of dynamic centre-surround adaptation.

C. Alejandro Parraga[1,2](Alejandro.Parraga@cvc.uab.es), Arash Akbarinia[1,2]; [1]Computer Vision Centre, Universitat Autònoma de Barcelona, Spain, [2]Computer Science Department, Universitat Autònoma de Barcelona, Spain

Colour constancy refers to the human visual system's ability to preserve the perceived colour of objects despite changes in the illumination. Its exact mechanisms are unknown, although a number of systems ranging from retinal to cortical and memory are thought to play important roles. The strength of the perceptual shift necessary to preserve these colours is usually estimated by the vectorial distances from an ideal match (or canonical illuminant). In this work we explore how much of the colour constancy phenomenon could be explained by well-known physiological properties of V1 and V2 neurons whose receptive fields (RF) vary according to the contrast and orientation of surround stimuli. Indeed, it has been shown that both RF size and the normalization occurring between centre and surround in cortical neurons depend on the local properties of surrounding stimuli. Our stating point is the construction of a computational model which includes this dynamical centre-surround adaptation by means of two overlapping asymmetric Gaussian kernels whose variances are adjusted to the contrast of surrounding pixels to represent the changes in RF size of cortical neurons and the weights of their respective contributions are altered according to differences in centre-surround contrast and orientation. The final output of the model is obtained after convolving an image with this dynamical operator and an estimation of the illuminant is obtained by considering the contrast of the far surround. We tested our algorithm on naturalistic stimuli from several benchmark datasets. Our results show that although our model does not require any training, its performance against the state-of-the-art is highly competitive, even outperforming learning-based algorithms in some cases. Indeed, these results are very encouraging if we consider that they were obtained with the same parameters for all datasets (i.e. just like the human visual system operates).

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26.3002 Estimating illuminant by optimal color hypothesis model for scenes with various chromaticity-luminance distributions

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In order to achieve color constancy, the visual system needs to estimate an illuminant and discount it to retrieve surface colors in a scene. Many proposed algorithms only succeeded in part in accounting for this color constancy process in the visual system. Therefore we need a more comprehensive model to be applied for general scenes. Uchikawa et al. (2012) proposed the optimal color hypothesis, in which the visual system would choose the best-fit optimal color shell for a given chromaticity-luminance distribution of a scene to estimate an illuminant. The optimal color shell is uniquely determined in a chromaticity-luminance color space for a given illuminant. Kusuyama et al. (ICVS, 2015) formularized this hypothesis based on the least square method, and then verified this model by comparing illuminants calculated by this model with those obtained by observers in psychophysical experiments. The present study aimed at validating this model using other scenes. We compared performance of this model with those of other models based on mean chromaticity, mean L, M, S responses and chromaticity-luminance correlation. In experiments, observers adjusted chromaticity and luminance of a center test stimulus surrounded by 60 stimuli with no spatial gap so that it appeared as a full-white paper. We manipulated the chromaticity-luminance distribution of surrounding stimuli. Three black-body illuminants, 3000K, 6500K and 20000K were used as test illuminants. It was found that our optimal color model predicted observer's settings equally well for redness and blueness directions in MacLeod-Boynton chromaticity diagram in most conditions better than those of the other three models. These results confirmed that our optimal color model works well at least for conditions tested, suggesting that the visual system could estimate an illuminant utilizing the optimal color shell.

26.3003 Stable colorfulness perception of scene through haze

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The saturation of visual scene decreases by haze due to environments (e.g. fog) and optical properties of eyes (e.g. aging of crystalline lens). However, we would be able to maintain stable colorfulness perception of a scene if we have a mechanism to compensate deceased saturation by haze. We previously examined the influence of haze on the colorfulness perception of natural images using foggy filters, and showed that it was almost the same with and without the foggy filters even immediately after wearing the filters, suggesting a strong instantaneous colorfulness compensation mechanism (ICVS2015). Here, we further examine if the strength of colorfulness compensation is influenced by the pattern of stimuli. We tested conditions viewing natural images through actual foggy filters as well as simulated images, using a colorfulness matching method. Observers memorized the colorfulness of a stimulus image without foggy filters. Then they adjusted the colorfulness of a natural image through foggy filters (or a simulated foggy image) to match the memorized colorfulness of the image by controlling the metric chroma of the image. We examined natural images and also simple patterns such as the array of squares with single or multiple colors. Each observer run three sessions under each condition. Results show that colorfulness settings of images through the filters was almost the same as those without the filters in all conditions, suggesting that we can adjust our perception to deceased saturation by haze and maintain stable colorfulness perception for any stimuli. The variance of results was smaller for the natural images compared to other simple patterns in general, implying that the compensation of deceased saturation is more stable for natural scenes with complex information.

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26.3004 Sequential attraction in color perception

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It is well established that perceived colors are altered by simultaneously or successively presented neighbors, and mutual repulsion between contiguous colors has been attributed to lateral inhibition and adaptation. Here we present evidence for sequential attraction in color perception. This novel perceptual phenomenon could bias identification and discrimination measurements, and affect integration of color with form and motion. Serial dependencies for ambiguous motion, ambiguous figures, and orientation, have been attributed to integrating current input with past information, as part of pattern completion, inherent storage, continuity field, etc. The underlying prior being that constancy of object properties is generic in the physical world, so that sudden change in object properties is attributed to environmental transients. We used sequences of colors, within and across color mechanisms, to examine the neural substrate of sequential attraction across abrupt changes. On each trial, observers fixated a 4o colored target disk for 500 millisecond. A random noise square glided over the disk revealing a changed color. Observers adjusted the color to match the target. The noise square again occluded the disk and revealed the next target. Sequential targets were chosen randomly from an isoluminant red-green line, or the circumference of a color circle. The signed error for matches along the red-green line, plotted against the signed deviation between the matched target and the preceding target, showed a skew-symmetry demonstrating that matches were attracted towards the color of the preceding target (3 color-normal observers). However, sequential attraction was not seen for matches around the color circle. Choosing between the two possibilities that sequential attraction happens within color mechanisms but not across, or that attraction happens within stimuli that are represented as a single dimension but not across multi-dimensional representations, requires further experimentation. Unraveling the neural processes of color attraction may help understand sequential dependencies in other domains.

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26.3005 Separating surface changes from illumination changes

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Color constancy is defined as the act of accurately extracting the color of a given surface under arbitrary changes of illumination. However, this also requires that one compensates for changes in surface reflectance properties, such as those due to environmental factors. We investigated the visual system's capacity to separate changes in surface reflectance from simultaneous changes in the illumination. Hyperspectral images were taken of tennis-table balls in a white chamber that was diffusely illuminated by a broadband light source. A blue ball and a yellow ball were photographed under a bluish daylight and a yellowish daylight illuminant, giving four images. Variations of reflectance and illumination were simulated by linearly interpolating between the recorded spectra of these four images. We had two tasks, during which 4 observers viewed sequential, random pairs of these images (2s presentation per image). In the first task, they stated whether the ball had changed, the illuminant had changed, or both had changed. In the second task, observers first saw examples of the most extreme illuminant and reflectance changes for our images. They were asked to memorize these references as a scale for illumination and reflectance change, in units of 0% to 100% change. Next, they were asked to use their memorized scale to judge the magnitude of illuminant and reflectance change between sequentially displayed pairs of images. On average, observers accurately identified 93% of the reflectance-only and 83% of the illumination-only changes, but they were worse at identifying combined reflectance/illumination changes, with 55% accuracy on average. Observers were consistent in their magnitude reports for each change, but they showed a tendency to overestimate intermediate changes and underestimate maximal changes. We suggest that, at least for our stimuli, the visual system is poor at handling the ambiguities introduced by simultaneous changes in reflectance and illumination.

26.3006 Illumination discrimination in the absence of a fixed surface reflectance layout

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We have previously shown that humans can discriminate changes in illumination and that sensitivity to such changes depends on the chromatic direction of the change and on the chromaticity of the surfaces in the scene. Here we explore the degree to which illumination discrimination taps a surface-independent representation. Specifically, we ask whether illumination discrimination remains possible when, unlike in our previous studies, the surface reflectances in the scene are shuffled as the illumination varies. Stimuli were rendered using RenderToolbox3 and viewed stereoscopically. On each trial subjects (N=10) viewed a scene illuminated by a target light followed by two test scenes — one illuminated identically to the target, another illuminated by a comparison light — and judged which matched the target. Across trials, the comparison light varied in chromaticity ("bluer", "yellower", "greener or "redder") relative to the target light (1-50 CIELUV ΔE units). The scenes were tiled with square surfaces, which were assigned one of 14 preselected surface reflectances; within a scene the area assigned to each reflectance was roughly equal. In one condition the surface reflectance assignment was fixed across scenes; in the other, the assignment varied randomly across the test and target scenes, while keeping the average scene reflectance roughly constant. With fixed surfaces, illumination discrimination was good and subject performance was similar to that measured in our previous studies. When the surfaces were shuffled, performance was significantly worse: for eight subjects, thresholds were systematically higher (by 14 ΔE on average); for the remaining two subjects, thresholds exceeded our largest step (50 ΔE) for at least one illuminant direction. Our results show that illumination discrimination is possible in the absence of fixed surface reflectance layout. Further research will attempt to determine whether subjects make the judgments based on a percept of scene illumination or whether they use task-specific strategies.

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26.3007 Estimation of illuminant in the white/gold and blue/black "dress" image

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It has been argued that individual differences in color appearance of #TheDress may occur as a consequence of color constancy mechanism working differently in individuals. To clarify this argument, we investigated what illuminants observers estimated in the "dress" image, and whether their estimates depended on their color names, i.e., white/gold or blue/black, used to specify the dress colors. In experiments we presented the original dress image and a horizontal stripe pattern (horizontal 19.3 x vertical 13.5 deg, 0.26 cy/deg square stripes) consisting of two colors as test stimuli on a calibrated LCD monitor. Two colors in the stripe pattern were made of blue and black colors averaged in the original dress image in a condition, and in other conditions one of two colors was chosen from a blue-to-white continuum and the other from a black-to-yellow continuum. Observers named two colors in the stimulus using eleven basic color terms and gold, silver and copper. They also selected a color patch, which represented a light illuminating the stimulus, from an array of color patches presented on the LCD monitor. The array consisted of color patches with various chromaticities and luminances. The results showed that when observers used white/gold to name the original dress image, they selected dark bluish illuminants, and when observers used blue/black, they selected bright yellowish illuminants. This tendency to select different chromaticity of an illuminant was also observed when the horizontal stripe pattern was used as the test stimulus although its luminance was not consistent with the case in which the original dress pattern was used. The present results showed strong correlation between stimulus color names and selected illuminant colors, suggesting that different effect of color constancy on illuminant estimation is a determining factor to yield individual differences in color naming of the "dress".

26.3008 Can high-pass filters remove the effects of illumination? A filter-based approach to understanding #theDress and other demonstrations of color constancy

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Because material reflectance remains invariant across illumination conditions, many theories of color constancy assume that an observer's perceptual goal is to infer material reflectance. According to these theories, one way to estimate reflectance is to discount the illumination in the scene based on the observer's previous experience. Here we explore an alternate approach based on the idea that global illumination usually affects low spatial frequency content and therefore can be removed from an image with a simple high-pass filter. We demonstrate that an object that appears to vary in color when photographed under blue, white, or yellow illumination does not change color when the images are filtered so as to remove the low spatial frequency information. The implication is that, to a first approximation, high spatial frequency content remains invariant to changes in global illumination and therefore can be used as a basis of color constancy. We propose that the cut-off frequency for the filter adjusts to the sizes of objects in the scene, which prevents desaturation. This filter approach can account for the Rubik's cube illusion (a canonical demonstration for color constancy). Lastly, we examine how high-pass filtering affects observer perceptions of #theDress. If high-pass filtering acts as a method for discounting illumination, then observers should be more likely to perceive the filtered versions of the dress as "blue-black." However, observers are more likely to report that the dress appears "white-gold" as more low spatial frequency content is removed. The results could be taken as support for the theory that observers are not trying to estimate material reflectance (a distal property) but are instead giving a response based on an image's high spatial frequency content (a proximal property). The results are consistent with other reports that suggest separate high and low spatial frequency processes for color constancy (Werner, 2014).

26.3009 Your Brain Doesn't Know: A Visual P300 Experiment of "The Dress"

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Whether The Dress is blue and black, white and gold, or just plain ugly, one thing is certain—it is guaranteed to generate passionate discussion. Lafer-Sousa et al. (2015) and Gegenfurtner et al. (2015) demonstrated substantial individual differences in the perceived color of The Dress. Here, we asked whether differences in perception of the ambiguous dress affect neural responses measured using electroencephalography (EEG) in a simple deviant-detection experiment. Our stimuli comprised three images (from Wired magazine), the original ambiguous photo and two whose luminance and color cast were manipulated to force either the blue/black or white/gold percept of the foreground dress. All three images had identical background luminance and color. Subjects viewed a stream of images (displayed for 700 ms; inter-stimulus interval 1000 ms) comprising one standard image

(80% of trials), and two randomly-occurring deviants (10% of trials each). Subjects were instructed to identify deviant stimuli via keypress. Each image served as the standard in one block of 500 trials, and as a deviant in two other blocks. We recorded EEG scalp potentials elicited by the onset of each stimulus while subjects performed this task. The visual P300 was reliably evoked by deviant images, consistent with the fact that the deviant detection task was relatively easy (behavioral accuracy >90%). We also observed stimulus-driven effects on the magnitude and latency of the P300. When the ambiguous image served as the standard, white/gold deviants elicited stronger responses than blue/black deviants. This effect did not depend on individuals' percepts of the ambiguous image; the P300 was independent of whether subjects perceived white/gold or blue/black. Our results suggest that early deviant detection processes respond to low-level stimulus characteristics and do not reflect perception of color category.

26.3010 **Perceived colors of the color-switching dress depend on implicit assumptions about the illumination** Christoph Witzel[1](cwitzel@daad-alumni.de), Chris Racey[2], J. O'Regan[1]; [1]Laboratoire Psychologie de la Perception -- CNRS UMR 8242, Université Paris Descartes, 45 rue des Saints-Peres, 75006 Paris, France., [2]Sussex Colour Group, University of Sussex, Sussex House, Falmer, Brighton, BN1 9RH United Kingdom.

Millions of internet users around the world recently challenged science by asking why a certain photo of a dress led different observers to have surprisingly different judgments about the color of the dress. We suggest that a simple explanation provides a complete account of why observers see the colours of "the dress" in fundamentally, apparently irreconcilable ways (http://lpp.psycho.univ-paris5.fr/feel/?page_id=929). The reason is that the photo allows two different implicit interpretations about the illumination of the dress. Because observers have different assumptions about the illumination in the photo they perceive different colors of the dress. We tested this idea in two experiments. In a first experiment we measured the perceived colours of the dress, and the estimated color of the illumination: we did this by using (1) a color naming and (2) a color adjustment procedure. Naming and adjustment results show that the perceived color of the dress is negatively correlated with the assumed illumination along the daylight axis. In a second experiment we attempted to steer how observers would see the colors of the dress by manipulating their assumptions prior to seeing the photo of the dress. Prior to showing observers the original photo, we presented them two kinds of images showing the dress with disambiguated illumination cues. Each of the two disambiguated images represents one of two possible interpretations of the illumination conditions in the original photo. Depending on which of the disambiguated images observers saw, they were inclined to see the colors of the dress in the original photo in one or the other way. These findings confirm the idea that the perceived colors of the dress depend on the assumptions about the illumination. The phenomenon illustrates the power of prior assumptions in perception.

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26.3011 **Correcting for induction phenomena on displays of different size** Marcelo Bertalmío[1](marcelo.bertalmio@upf.edu), Thomas Batard[1], Jihyun Kim[1]; [1]Universitat Pompeu Fabra, Spain

In visual perception, induction designates the effect by which the lightness and chroma of a stimulus are affected by its vicinity, shifting towards its surround (assimilation) or away from it (contrast) depending on stimulus size (Helson 1963, Fach and Sharpe 1986). When looking at an image on a display, observers commonly place themselves at a distance from the screen so that the angle of view is larger for larger displays. As a consequence, the visual induction phenomena will also change from one screen to another: the same image may show significant assimilation effects when viewed on a mobile phone, and less assimilation or even contrast when viewed in the cinema. In this work we introduce a model for visual induction based on efficient coding that extends that of (Bertalmío 2014). Given an input image, we convolve it with a kernel which should depend on the apparent image size, and the resulting image qualitatively replicates psychophysical data. This allows us to propose the following method by which an image could be pre-processed in a screen-size dependent way so that its perception, in terms of visual induction, may remain constant across different displays: -convolution of image I with kernel Sj produces image Oj that predicts the appearance of I at angle of view j, j=1,2; -a compensation kernel C12 is defined as the inverse Fourier transform of the ratio of the Fourier transforms of S1 and S2; -convolving I with C12 produces image Ip, and now convolution of this new image with S2 will produce O1, same as I with S1; in other words, if I was intended for screen 1, we can pre-process it with C12 to obtain Ip so that when Ip is viewed in screen 2 it has the same induction effects as I in screen 1.

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Spatial Vision: Crowding and periphery

Saturday, May 14, 2:45 - 6:45 pm

Poster Session, Banyan Breezeway

26.3012 **Visual Performance Fields in Motion** Leslie Krause[1](lkrause1@carthage.edu), Jennifer Anderson[2], Michael Levine[2,3], E. Leslie Cameron[1,2]; [1]Department of Psychological Science, Carthage College, [2]Department of Psychology, University of Illinois at Chicago, [3]Laboratory of Integrative Neuroscience, University of Illinois at Chicago

Visual performance fields are inhomogeneous. Performance is better on the horizontal than the vertical meridian (Horizontal Vertical Anisotropy (HVA)) and is often better in the lower visual field (Vertical Asymmetry (VA)). Performance is particularly poor on the vertical meridian above the point of fixation (the north effect), and sometimes, below the point of fixation (the south effect). Visual field inhomogeneities are primarily explored using stationary stimuli, such as Gabor patches and inhomogeneities become more pronounced as spatial frequency (SF) increases. Relatively few studies have described visual field inhomogeneities using moving stimuli and none have explored the effect of SF. This study examined visual field inhomogeneities with drifting Gabors at 4 SFs (0.5-8cpd). Five participants performed a 2AFC direction discrimination task with 1 degree Gabors drifting at 4 Hz. Stimuli were presented at one of 8 equally-spaced target locations, at 4.5 deg eccentricity. Visual field inhomogeneities were quantified by fitting data with hemi-ellipses (see Anderson, Cameron & Levine, 2014). An HVA was observed at all SFs. Surprisingly, a VA was not observed. In fact, performance was better in the upper visual field at all SFs except the 0.5cpd condition. A north effect was observed at all SFs with the exception of 0.5cpd and a trend for a south effect emerged at 2 and 4cpd, but was not evident at 0.5 and 8cpd. In a control study a north effect was observed at low SF when the target size was doubled (i.e., more cycles in the Gabor). These results suggest that the ability to detect direction of motion is similar to the ability to detect orientation. Both capabilities may depend on a more primitive detection process at some earlier processing stage.

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26.3013 **Contrast Sensitivity Across the Nasal and Temporal Peripheral Visual Fields: Measurements with Gabor Sinusoids** Russell Adams[1,2](michelem@mun.ca), Michele Mercer[1], James Drover[1,2]; [1]Department of Psychology, Faculty of Science, Memorial University, St Johns, NL Canada, [2]Discipline of Pediatrics, Faculty of Medicine, Memorial University, St Johns, NL Canada

Purpose: It is now well accepted that contrast sensitivity (CS) is the most comprehensive measure of human spatial vision. Previously (VSS 2015), we reported the first data for CS measurement in both the near and far periphery, using Gaussian filtered sine waves (Gabor patches). However, in order to better understand underlying neural mechanisms and to provide normative data for those interested in assessing peripheral eye disease (e.g. glaucoma, RP, retinal degeneration), here we measured CS across both the nasal and temporal retinal fields. Methods: Using a conventional staircase procedure, right eyes from 10 healthy emmetropic adults (16 to 55 yr.) were tested 10 times repeatedly with vertically-oriented sinusoidal Gabor patches that ranged logarithmically in spatial frequency (SF) from 0.375 to 18 cy/deg and in contrast from 0.001 to 0.30. Contrast thresholds at each SF were obtained foveally and from 100 to 800 within the temporal and nasal visual fields. Results: As expected, with increasing eccentricity, the drop-off in peripheral CS from foveal viewing (Mfoveal across SF = 145.9 CS units) is substantial. However, the pattern differs between the two fields: Nasal sensitivity drops off rapidly over the first 200 (to 10.5 units) but then completely stabilizes until 600 (10.6 units). In contrast, temporal sensitivity decreases more steadily but eventually yielding a lower CS level at 600 (5.6 units, $p < 0.05$). Conclusions: Human CS can be measured reliably up to 600 in both the nasal and temporal visual fields. Overall, CS decreases by about 0.24 log units per 10o eccentricity, but the rate of reduction is at first rapid and then plateaus in the nasal field, and is much more steady in the temporal field. These behavioural data are consistent with anatomical data describing the relative ratios of P ganglion cells in the peripheral retina.

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26.3014 The effect of task and target size on the north effect

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Several studies have reported that orientation discrimination in the upper visual field is poorest directly above fixation (the north effect). Performance improves as stimuli appear further from the vertical meridian (VM), up to ~1.5 deg from the VM (Cameron, Levine & Anderson, VSS 2015). The neural mechanism underlying the north effect is not well understood. One behavioral approach that might lead to a better understanding is to measure performance on tasks that do not rely on orientation-tuned mechanisms. In this study, we explored the effect of visual field location on a simple detection task. In addition, we manipulated stimulus size to explore the extent to which mechanisms near the VM could counteract the north effect. We measured performance on a yes-no detection task with gray squares of two sizes (0.15 and 0.3 deg.) presented at one of 36 locations, concentrated within 30 deg. of the VM at 4.5 deg. eccentricity. We also measured performance on a 2AFC orientation discrimination task of 2cpd (1 and 2 deg.) and 8cpd (0.5 and 1 deg.) Gabors. Target contrast was chosen for each observer and task in pilot threshold tests such that overall performance was maintained at ~80% correct. Visual performance fields were fit with hemi-ellipses (Anderson, Cameron & Levine, 2014) and we computed difference ratios (predicted performance from the hemi-ellipse fit minus observed performance, at each location) and examined how they varied with angular degree. In all conditions, performance improved (ratios decreased) as stimuli appeared further from the VM. A north effect was observed under all conditions, including simple detection. Surprisingly, size did not mitigate the effect. In fact, in some cases (8cpd and detection task) the effect became more pronounced. These results suggest that the north effect is not solely dependent on orientation mechanisms and may rely on more primitive mechanisms.

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26.3015 Detection of occluding targets across the visual field

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Detecting spatial targets in complex backgrounds is a fundamental visual task. Detectability decreases with increasing retinal eccentricity. Detectability is also affected by the properties of the background surrounding and under the target, an effect known as masking. Previous research has used additive targets, where the target intensities are added to the background. Previous research shows that background contrast explains much of the variance in foveal and peripheral detectability. Furthermore, the masking of additive targets operates in a lawful manner: Target threshold power increases linearly with background contrast power. In natural viewing, however, targets occlude the background, replacing background features with target features. It is currently unknown whether the laws that apply to additive targets extend to occluding targets. We began our investigation with an experiment using two occluding targets (a uniform disc and vertical edge) embedded in 1/f noise at varying eccentricities. The uniform disc had a luminance of 25 cd/m2. The vertical edge target had the same mean luminance and a contrast of 17% RMS. The average luminance of the background was fixed at 25 cd/m2. An eccentricity psychometric function was measured for five background contrasts (3%, 10%, 17%, 31%, 45% RMS). The eccentricity threshold is the eccentricity where detection accuracy falls to 75%. A lower threshold indicates that a target must be presented closer to the fovea to be detected. We find that eccentricity thresholds decrease with background contrast for the vertical edge target, but increase for the uniform disc target. This is very different from additive targets, where detectability always decreases with background contrast. While this difference makes intuitive sense, it highlights the need for measuring and modeling detection of occluding targets. We are currently extending our measurements to natural backgrounds and are developing a model of detection to account for both additive and occluding targets.

26.3016 Assessing the invisibility of spatial disarray in peripheral vision

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One of the defining characteristics of peripheral vision is that positional information is largely degraded. In a psychophysical experiment we investigate how positional uncertainty affects appearance within peripheral vision. To this aim we generated spatially disarrayed versions (eidolons) of natural images from the UPenn database. The disarray was determined by a random field confined to a 10° circular area within the image and was characterized by the maximum displacement which could be applied to a pixel (reach). In each trial, observers were exposed to two versions of the same image, the original image and the disarrayed eidolon in a random sequence. Each picture was shown for 1.5 s, interleaved for .5 s by a phase-scrambled image. Observers reported which image appeared disarrayed. Between trials we varied both the reach and the eccentricity of the disarrayed patch. Observers were forced to fixate either the center of the disarrayed patch, which was located left or right in the image, or at locations 10°, 20°, 30° or 40° towards the other side of the image. Accuracy in disarray identification as a function of reach was fitted through psychometric curves, yielding reach thresholds at each eccentricity. The data by six observers showed a clear linear increase in the reach thresholds as a function of eccentricity up to 30°, with average foveal reach thresholds of .143° (std .039) and slopes of .015 (std .005). Disarray detection proved much harder at 40° eccentricity, largely independent of reach. Our results show that features can be displaced to a substantial extent (over .5°) in peripheral vision, before an image loses its perceptual quality of naturalness, in accordance with the hypothesis that in peripheral vision positional information is degraded before it reaches awareness. Eidolons potentially offer a way to visualize the appearance of peripheral stimuli in foveal vision.

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26.3017 Seeking summary statistics that match peripheral visual appearance using naturalistic textures generated by Deep Neural Networks

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An important hypothesis that emerged from crowding research is that the perception of image structure in the periphery is texture-like. We investigate this hypothesis by measuring perceptual properties of a family of naturalistic textures generated using Deep Neural Networks (DNNs), a class of algorithms that can identify objects in images with near-human performance. DNNs function by stacking repeated convolutional operations in a layered feedforward hierarchy. Our group has recently shown how to generate shift-invariant textures that reproduce the statistical structure of natural images increasingly well, by matching the DNN representation at an increasing number of layers. Here, observers discriminated original photographic images from DNN-synthesised images in a spatial oddity paradigm. In this paradigm, low psychophysical performance means that the model is good at matching the appearance of the original scenes. For photographs of natural textures (a subset of the MIT VisTex dataset), discrimination performance decreased as the DNN representations were matched to higher convolutional layers. For photographs of natural scenes (containing inhomogeneous structure), discrimination performance was nearly perfect until the highest layers were matched, whereby performance declined (but never to chance). Performance was only weakly related to retinal eccentricity (from 1.5 to 10 degrees) and strongly depended on individual source images (some images were always hard, others always easy). Surprisingly, performance showed little relationship to size: within a layer-matching condition, images further from the fovea were somewhat harder to discriminate but this result was invariant to a three-fold change in image size (changed via up/down sampling). The DNN stimuli we examine here can match texture appearance but are not yet sufficient to match the peripheral appearance of inhomogeneous scenes. In the future, we can leverage the flexibility of DNN texture synthesis for testing different sets of summary statistics to further refine what information can be discarded without affecting appearance.

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26.3018 **Effects of Stimulus Category and Task Difficulty in the Temporal Window of Crowding**
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A peripheral target is more difficult to identify when it is surrounded by flankers. This effect of crowding has been extensively investigated in spatial and temporal domains, with the majority of studies focused on the spatial properties of targets and flankers and their spatial relationships. The current study aims to uncover the effect of task difficulty and stimulus category on the temporal interactions between the target and flankers. Specifically, we examined whether orientation identification of Gabor patches and letters among flankers had different temporal windows. Targets were either Gabor patches (two orientations in easy condition and four orientations in difficult condition) or letters (letter-T in easy condition and letter-G in difficult condition), and they were presented in the right or left peripheral area with the target centered at 8° from fixation surrounded by four flankers. The flankers were presented at 7 different SOAs relative to the target presentation (-150, -100, -50, 0, 50, 100, 150 ms). Results from five subjects show that, consistent with the literature, crowding effect was the strongest when the target and flankers were presented simultaneously (SOA=0), and there was an asymmetry between flankers presented before (SOA < 0) and after (SOA > 0) the target. When the target was followed by flankers the performance was worse than when the flankers were followed by the target. However, our current data do not show a category nor a task difficulty level dependence, in that the temporal windows of target-flanker interaction are similar for the four types of stimuli used in this study. Our next step is to examine the temporal window of target-flanker interaction using more complex stimuli such as objects or faces.

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26.3019 **Sparse Coding under Saccade-Confounded Statistics**
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Image encoding in visual cortex is thought to be adapted to natural scene statistics. Spatial attention may selectively enhance the acquisition of these statistics. The effect of such attention-gated learning may be especially pronounced in peripheral vision, as the shift of attention to a peripheral visual location is tightly coupled to the initiation of a saccade. We hypothesize that this attention-saccade link biases peripheral visual input, introducing an eye-movement-related confound to the veridical image statistics (Nandy & Tjan, 2012). This, in turn, is predicted to shape learned spatiotemporal receptive fields and lateral interactions in ways that predict deficits of peripheral form vision such as crowding. To model the effect of saccade-confounded statistics on image encoding in V1, we simulated saccades across natural image data and mapped the resulting videos to a model cortical surface with eccentricity-dependent magnification and resolution. We then learned a space-time sparse coding dictionary on samples from a circular patch of model cortex – representing a target location and a laterally-interacting surround, all under an attentional spotlight centered on the target – in a temporal window adjusted to the duration of a transient spatial attention episode (Sperling & Weichselgartner, 1995). This peripheral spacetime dictionary is spatially similar to foveal dictionaries, but with a preference for movement toward the fovea. For a given basis trained on peripheral inputs, only a subinterval in time contains a structured pattern. This subinterval can appear at any time in the basis. The unique features of this dictionary – anisotropic movement preference and a narrow temporal window with variable onset delay – point toward a role for peripheral vision that may differ more substantially from foveal vision than previously thought.

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26.3020 **Myopic Eyes See Better in a Crowd**
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The eyes of myopes are larger, both wider and especially longer, than the eyes of normally-sighted, emmetropic individuals. Even with best-corrected foveal vision, myopic peripheral vision is generally found to be worse than emmetropic peripheral vision. However, the functional vision of the periphery is limited not by acuity or contrast sensitivity but by visual crowding, the phenomenon by which visible targets become harder to identify in clutter. Because of the stretched myopic retina, objects projected onto the peripheral retinal surface of myopic eyes subtend the same retinal angle, but are spaced farther apart than on an emmetropic retina. We ask whether retinal angle or retinal spacing determines crowding. We measured letter acuity as well as radial and tangential crowding zones at 5, 10, and 15 degrees of eccentricity in emmetropic and best-corrected myopic observers. Consistent with previous results, peripheral letter acuity was worse in myopic than emmetropic subjects. We also confirmed the radial/tangential crowding asymmetry in both myopic and emmetropic observers: radial crowding zones were larger than tangential crowding zones by a factor of 2. Critically, our data show that both radial and tangential spatial interference zones in myopic eyes are smaller than in emmetropic eyes. This finding suggests that crowding zones may be determined by retinal spacing rather than by retinal angle. Although myopia is generally thought of as a visual impairment, and clearly hinders sensory aspects of visual function, our data suggest that the elongated retinal surface of myopic eyes may provide a functional benefit by extending the spacing within which peripheral targets are crowded. Our findings raise the possibility that at the supra-threshold object sizes and contrasts that dominate natural vision, interactions between central and peripheral vision might differ between myopes and emmetropes. These differences might play a neglected role in the development and progression of myopia.

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26.3021 **Dissociable effects of crowding for judgements of colour and motion**
John Greenwood[1](john.greenwood@ucl.ac.uk), Michael Parsons[1]; [1]Experimental Psychology, University College London

In peripheral vision, object recognition is impaired by clutter. This crowding effect disrupts the identification of a diverse range of features including orientation, motion, depth and colour. Although current models depict crowding as a singular object-selective mechanism that affects these features simultaneously, rather than multiple feature-specific instances that operate independently, prior research is equivocal. We examined crowding for colour and motion, two features that allow a strong test of feature independence (e.g. given prior findings for visual search). Cowhide stimuli were presented 15 degrees in the periphery; observers reported either the target hue (blue/purple) or its carrier direction (CW/CCW of upwards). To assess the independence of these judgements, we first established that two key aspects of crowding, shown previously for orientation, are also true for colour and motion. First, crowded errors are systematic: identification errors for both target hue and direction were biased, generally towards the identity of the flankers. Second, crowding is selective for target-flanker similarity: motion crowding was strong when target-flanker directions were similar and weak when they differed, and likewise for colour crowding. These findings allowed us to test the independence of crowding for hue and direction by requiring observers to indicate both features. An object-selective mechanism predicts that when crowding is weak for one feature (e.g. colour) and strong for the other, errors for both features should be either unaffected or reduced (i.e. that crowding is all-or-none). In contrast, our results follow the predictions of independent feature-selective processes: when crowding was weak for colour and strong for motion, errors were reduced for colour but remained for motion. Likewise, colour errors predominated when crowding was strong for colour and weak for motion. Given this double dissociation, we argue that crowding is not a singular process but rather a feature-specific pooling operation that occurs throughout the visual system.

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26.3022 **Visual field shape influences critical spacing in visual crowding**
Adeola Harewood[1,2](harewood@berkeley.edu), Francesca Fortenbaugh[5], Lynn Robertson[1,2,3,4], Michael Silver[1,2,4]; [1]Vision Science Graduate Group, University of California, Berkeley, [2]School of Optometry, University of California, Berkeley, [3]Psychology, University of California, Berkeley, [4]Helen Wills Neuroscience Institute, University of California, Berkeley, [5]Department of Veterans Affairs, Boston, MA

Behavioral performance is better in the lower than in the upper visual field for a variety of perceptual tasks, including visual crowding. We recently showed that the lower visual field advantage for visual crowding could be accounted for by asymmetry in the shape of the visual field along the vertical meridian. Here, we are continuing this work by studying visual field asymmetries in critical spacing - the minimum distance between a target and its flankers that is needed to enable a certain level of performance on a crowding task. Upper and lower visual field extents were measured in each participant with a Goldmann perimeter. Participants (n=13) then completed a crowding task in which they discriminated the orientation of a target grating in the presence of flanker gratings. The spacing between gratings was altered on each trial using an adaptive staircase to find the 79% performance threshold (i.e., critical spacing). The target grating was always on the vertical meridian, in either the upper or lower visual field. We found smaller critical spacing in the lower visual field than in the upper visual field when stimuli were placed at the same eccentricity in units of degrees of visual angle (p=.03), consistent with a lower visual field advantage. However, when stimulus locations were matched based on percentage of visual field extent instead of in degrees of visual angle, critical spacing for the stimuli in the lower matched condition was similar to that in the upper visual field (p=.80), and critical spacing in the upper matched condition was similar to that in the lower visual field (p=.57). We are currently assessing the effects of spatial attention on critical spacing and examining the relationship between visual field shape and critical spacing for a range of eccentricities.

26.3023 **Behavioral and neurophysiological characterization of visual crowding in macaques** Christopher Henry[1], Adam Kohn[1]; [1]Dominick P. Purpura Department of Neuroscience, Albert Einstein College of Medicine

Visual crowding is a phenomenon whereby the features of objects viewed peripherally are rendered less discriminable by adjacent objects in the visual field. Crowding has been well studied in humans; but little is known about crowding in animal models where neurophysiological recordings are tractable. We trained an awake monkey on an orientation discrimination task and used a psychophysical reverse-correlation paradigm to characterize visual crowding from adjacent locations in the visual field. Distractors at some locations led to errors that were consistent with the distractor orientations (indicative of substitution or averaging). At other locations, incorrect judgments were inconsistent with the distractor orientation (indicative of repulsion or induced tilt). Thus, even within a single stimulus array, stimuli at distinct locations in the visual field had opposing influences on the judgment of target features. Similar behavioral results were found in one human subject. In parallel, we asked how crowding affected the neuronal encoding of orientation information. We recorded the responses of neuronal populations in anesthetized macaque V1 to target gratings, presented in isolation or surrounded by distractor gratings. To assess crowding, we applied linear discriminant analysis to V1 population responses to pairs of targets with offset orientations. Decoders trained on responses to isolated stimuli had significantly worse performance on responses to crowded stimuli, across a wide range of task difficulties. Performance deficits were also apparent when decoders were trained on crowded responses. Shuffling the neuronal responses to remove correlations reduced decoding performance, but crowding was still evident, suggesting that it arises in part from effects on the responses of individual neurons. These results demonstrate that crowding involves a loss of sensory information at the first stages of cortical processing; however, as crowding effects in V1 were weaker than those seen behaviorally, maladaptive pooling by downstream circuits is also likely to contribute.

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26.3024 **The perceptual effects of crowding in amblyopic and peripheral vision** Alexandra Kalpadakis-Smith[1](alexandra.smith.13@ucl.ac.uk), Vijay Tailor[2,3], Annegret Dahlmann-Noor[3], John Greenwood[1]; [1]Experimental Psychology, University College London, London, UK, [2]Strabismus and Paediatric Service, Moorfields Eye Hospital, London, UK, [3]NIHR Biomedical Research Centre at Moorfields Eye Hospital NHS Foundation Trust, London, UK

For children with strabismic amblyopia (a developmental disorder of vision linked with ocular deviation), foveal vision can become affected by crowding: objects that are visible in isolation become indistinguishable in clutter. Crowding also affects the visual periphery of adults, where it produces systematic errors in object identification: the target object appears to be either averaged with the flanker identities (assimilation), or replaced by them (substitution). If the same mechanisms underlie crowding in amblyopia and the adult periphery, then errors in amblyopic crowding should be similarly systematic. Alternatively, amblyopic errors may be random, driven by factors such as perceptual distortions. To examine these perceptual effects we tested children, aged 3-9, with strabismic amblyopia. Children wore stereoscopic shutter-glasses and reported the orientation of a target 'Vac-Man, similar to a Landolt-C. We first measured acuity (threshold size) and the spatial extent of foveal crowding. Then, to investigate the perceptual effects of crowding, we used a matching task: children adjusted a reference Vac-Man to indicate the perceived target orientation. To examine the effect of target-flanker similarity, target-flanker differences were set at 30- and 90-degrees. These tests were also conducted on adults with normal vision. We find that the addition of flankers impairs matching performance in both children and adults. Flankers with a 30-degree difference were most disruptive, while 90-degree offsets allowed more accurate matching and a partial release from crowding. Children's precision was strongly affected under crowded conditions, with random errors common. However, we find strong evidence of substitution, with children frequently reporting the identity of the flankers. Although less often than adults, children also report orientations around the target-flanker average, showing evidence of assimilation. We thus argue that despite an increase in random errors, the perceptual outcomes of amblyopic crowding generally resemble those in the adult periphery, suggesting a common underlying mechanism.

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26.3025 **The serial dependence of perception in crowds** Mauro Manassi[1](mauro.manassi@berkeley.edu), Alina Liberman[1], Wesley Chaney[1], David Whitney[1]; [1]University of California, Berkeley, Department of Psychology, Berkeley, CA, USA

Despite an ever-changing and noisy visual world, our visual experience appears remarkably continuous and stable over time. Recently, orientation and face perception were shown to be biased towards previous percepts of orientation and faces, respectively (Fisher & Whitney, 2014; Liberman et al., 2014). This serial dependence effect was proposed as a mechanism to facilitate perceptual stability, compensating for variability in visual input. A key unanswered question is whether serial dependence operates in complex environments. Here, we tested whether serial dependence occurs in context, examining two main cases of contextual modulation. First, crowding: the deleterious influence of nearby objects on object perception. We presented a sequence of oriented Gabors and asked observers to adjust the orientation of a bar to match each Gabor's orientation. In the crowding condition, the Gabor was flanked by four additional Gabors. In the non-crowded condition, a single Gabor was displayed. We observed a classical serial dependence effect in the non-crowded condition: perceived orientation was biased toward the orientation of the previously presented Gabor. However, when the previous Gabor was crowded, the serial dependence effect on the following single Gabor ceased. Second, summary statistics: the beneficial ensemble perception of multiple objects. We presented a 3x3 array of nine Gabors with random local orientations, and asked observers to adjust a bar's orientation to match the ensemble orientation. We found strong evidence for serial dependence: the reported ensemble orientation was pulled toward the orientation of the previous Gabor array. Further controls showed that serial dependence occurred at the ensemble level, and that observers averaged 5/6 Gabors per trial. Our results show that serial dependence does not occur in crowded viewing conditions. However, serial dependence can still occur between summary statistical representations. Hence, we provide a mechanism through which serial dependence can maintain perceptual stability in complex environments.

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26.3026 **Crowding beyond Bouma's bound** Jeffrey Nador[1,2](jeff.nador@gmail.com), Adam Reeves[1]; [1]Dept. of Psychology, Northeastern University, Boston MA 02115, [2]Dept. of Psychology, Wright State, Dayton, Ohio

Previous research has demonstrated that applying onset transients to crowded targets can improve their orientation discriminability (Greenwood, Sayim & Cavanagh, 2014), but does not influence the spatial extent of flanker interference (critical spacing). At last year's VSS, we argued that this effect depends on observers' endogenous attention to the target location. Indeed, when target-flanker spacing and eccentricity are varied randomly from trial to trial, the effect of the transient is reversed – hindering target identification only at near spacing. Method: on each trial, observers saw an RSVP stream of letters at fixation, while 2 target Gabors appeared, one left and one right of fixation, throughout each 1s long trial. Targets were flanked by similarly-oriented Gabors. They were presented at 4 or 8 deg eccentricity, with center-to-center spacings of ¼, ½, or ¾ target eccentricity, randomized trial-to-trial. Observers shifted endogenous attention and evaluated the tilt of the Left or Right target Gabor depending on whether the letter 'L' or 'R' appeared at a randomized time during the RSVP. Results: Crowding was independent of target-flanker spacing, and blinking the target at near spacings hindered performance immediately following the endogenous attentional shift. However, when the concurrent RSVP task was replaced with an arrow indicating Left or Right prior to each trial, crowding decreased at wider spacings, with critical spacing roughly equal to ½ eccentricity (Bouma's bound). These effects can be explained if (1) during an attention shift, the attended region is more than 18 deg across, and (2), once attention is focused enough to exclude the flankers, crowding is reduced. Before then, blinking the target hurts at near spacing because it improves processing of all the stimuli in the attended region - not just the target, but also the flankers.

26.3027 **Does an experimentally induced preferred retinal locus alter crowding?** Kilho Shin[1](kilhoshi@usc.edu), Bosco Tjan[1,2]; [1]Department of Psychology, University of Southern California, Los Angeles, [2]Neuroscience Graduate Program, University of Southern California, Los Angeles

The spatial extent of crowding is elongated toward the anatomical fovea. Nandy & Tjan (2012) argued that this anisotropy is the result of acquiring image statistics under saccadic eye movements, which included uncompensated image movements caused by saccades. This theory predicts that the shape of the crowding zone may change if saccades are no longer referenced to the fovea, as in patients who have adopted a preferred retinal locus (PRL) for fixation after central field loss. Recently, our group has developed a technique to induce a PRL in normally sighted individuals using a simulated central scotoma (Kwon, Nandy & Tjan, 2013). Here we tested whether this experimentally induced PRL could lead to the predicted changes in crowding zones. Seven observers participated in 20-hours of PRL training, using the Kwon et al. (2013) method. We measured the two-dimensional crowding zone before and after training at 2 locations: the prescribed PRL location in the upper left visual field (eccentricity = 6.5°, 30° left of the vertical meridian) and a peri-PRL location positioned symmetrically in the right upper field. Under the condition of simulated central scotoma and after 20 hours of training, all seven observers developed a PRL at the prescribed location, with their saccades re-referenced to the PRL. We have thus replicated the findings of Kwon et al. (2013) and extended them to a prescribed (as opposed to spontaneously emerging) PRL. PRL training had a main effect in reducing crowding along the radial direction ($p < 0.05$). This result is consistent with a rounding of the crowding zone at the PRL location, as observed in AMD patients by Chung (2013) and predicted by Nandy & Tjan. However, evidence for the predicted reorientation of the crowding zone in the peri-PRL location was equivocal. Experimentally induced PRLs had an effect on crowding, albeit limited.

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Spatial Vision: Optics, contrast, and shape

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3028 **Optically correcting visual acuity beyond 20/20 improves visual perception: A cautionary tale for studies of special populations** Lisa Cruz[1](cruz01@g.harvard.edu), Brian Keane[1,2,3], Sabine Kastner[4,5], Thomas Papathomas[3,6], Steven Silverstein[1,2]; [1]University Behavioral Health Care, Rutgers, The State University of New Jersey, [2]Department of Psychiatry, Rutgers, Robert Wood Johnson Medical School, [3]Center for Cognitive Science, Rutgers, The State University of New Jersey, [4]Princeton Neuroscience Institute, Princeton University, [5]Department of Psychology, Princeton University, [6]Department of Biomedical Engineering, Rutgers, The State University of New Jersey

Background. The vast majority of studies that examine visual processing in special populations ensure that subjects have normal or corrected-to-normal vision, without also reporting whether subject groups are matched on visual acuity (VA) within the normal range. This is problematic because a host of factors impact VA (e.g., aging, schizophrenia) and because optimal VA among healthy adults is better than 20/20. Therefore, we ask: Does refractive error within the normal range alter visual performance? Methods. Ten healthy adults with 20/20 uncorrected binocular VA performed three perceptual tasks—once without eyeglasses and once with eyeglasses so that they could read an additional line (0.11 logMAR units) on a logarithmic eye chart. In the contour integration (CI) task, subjects located an integrated shape embedded in varying quantities of randomly-oriented noise elements; in the collinear facilitation (CF) task, subjects detected a low-contrast element flanked by collinear or orthogonal high-contrast elements; in the discrimination task, subjects discerned the orientation of four briefly-presented, high-contrast pac-man elements. Spatial frequency was modulated in the CI and CF tasks (4-12 cycles/deg) by scaling the entire display. Results. Optical correction enabled observers to integrate contours under noisier conditions ($p=.008$), detect elements of lower contrast ($p=.001$) and discriminate orientation differences of smaller magnitude ($p=.04$). When elements were composed of high (rather than lower) spatial frequency, optical correction conferred a greater benefit for contour integration ($p=.003$) and a marginally greater benefit for contrast sensitivity ($p=.07$). Conclusions. Previous studies reporting contour integration, contrast sensitivity, or orientation discrimination effects in aging, development, or psychiatric disorders may need to be re-evaluated if they did not match for VA within the normal range. Our results also offer a surprisingly powerful explanation of individual differences and show that modest reductions in refractive error within the normal range strongly improve visual perception.

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26.3029 **Retinal Image Statistics During Real-World Visual Experience** Matthew Peterson[1](mfpeters@mit.edu), Jing Lin[1], Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Sciences, MIT

The past few decades have seen rapid growth in the study of the core principles of Natural Systems Analysis (NSA; Geisler, 2008): that the computations employed by the visual system are the product of evolutionary optimization for the sensory evidence (i.e., images) and tasks critical for survival. A core tenet of NSA posits that a deep understanding of these systems requires knowledge of the properties of the visual environment in which they operate. Prior studies have typically analyzed sets of narrow field-of-view static photographs that have not been selected to reflect everyday visual experience. Critically, the absence of fixation data for these images prohibits the assessment of the actual images that land on the retina during real-world conditions. Thus, the degree to which these images faithfully represent real-world visual experience is unclear. Here, we detail the systematic collection and analysis of the Retinal Image Statistics (RIS) experienced during everyday behavior. Twenty-four subjects walked around the MIT campus as naturally as possible while a mobile eye-tracker and supplementary wide field-of-view, high-resolution camera recorded the surrounding visual environment and gaze position. The fixation data was used to compute the actual retinal images subjects experienced. Additionally, we dissociated head/body motion from eye movements by computing and controlling for global optical flow across successive frames. Machine learning algorithms allowed us to reliably identify individual subjects from the spatiotemporal statistics of head/body/eye movements (direction, magnitude, and frequency) and the RIS of fixated regions. Further, we found that the magnitudes of head and eye movements during real-world vision raise possible concerns as to the validity of laboratory-based paradigms incorporating fixed head, centrally-presented images. We conclude by discussing new approaches in machine and human vision research that are made possible by this framework and our expanding database of dynamic real-world retinal images.

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26.3030 **The independent components of binocular images reflect the spatial distribution of horizontal and vertical disparities** David Hunter[1](dwh5@st-andrews.ac.uk), Paul Hibbrad[2]; [1]School of Psychology and Neuroscience, University of St Andrews, [2]Department of Psychology, University of Essex

The geometry of binocular vision is such that the expected distributions of horizontal and vertical disparities vary from one location in the image to another. Firstly, binocular fixation means that disparities will be smallest in the centre of the image. Secondly, in the natural environment there is a statistical relationship between the height in the visual field and distance, such points lower in the retinal image tend to be closer to the observer. From this, we expect more crossed horizontal disparities in the lower half of the image. Finally, this height-in-the-field effect, combined with the origin of vertical disparities in differential perspective, creates a predictable distribution of vertical disparities. Specifically, we expect points to be shifted downwards in the left eye in the bottom left quadrant of the image, and upwards in the left eye in the bottom right quadrant. We tested the influence of these effects on the disparity tuning of independent components learned from natural binocular images. 139 binocular image pairs were divided into 4 quadrants and 3 eccentricities, and ICA was performed independently for each of the resulting 12 regions. Position disparity tuning of the resulting components was calculated by measuring the shift in their receptive field locations in the two eyes. The distribution of horizontal disparity tunings became broader with increasing disparity, there was a bias towards crossed disparities in the lower half of the image, and towards uncrossed disparities in the upper half. In the lower half of the image, vertical disparities tended to code for lower positions in the left eye in the left half of

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the image, and for higher positions in the left eye in the right of the image. The distributions of positional disparity tunings learned through ICA therefore reflect the expected distributions of disparities in natural images.

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26.3031 **Brief presentation enhances various simultaneous contrast effects** Sae Kaneko[1,2,3](sakaneko@ucsd.edu), Stuart Anstis[3], Ichiro Kuriki[2]; [1]Japan Society for the Promotion of Science, [2]Research Institute of Electrical Communication, Tohoku University, [3]Department of Psychology, University of California, San Diego

Kaneko & Murakami (2012) showed that simultaneous contrast for brightness and for color (saturation-shift type) are both enhanced by briefly presenting the stimulus. Simultaneous contrast is a universal phenomenon seen across many visual features. So how universal is the inverse relationship between the strength of simultaneous contrast and the stimulus duration? In the first study, we examined the relationship between the simultaneous tilt contrast (a.k.a. tilt illusion) and stimulus duration. A vertical test grating (2 cpd sinusoidal) and a tilted surrounding grating (inducer) appeared repeatedly and subjects adjusted the orientation of the comparison grating to make it parallel to the test. Test and inducer appeared simultaneously and their duration was either 10 ms or 500 ms. When the inducer was tilted 15 deg away from the test, the tilt contrast effect was more than doubled for 10 ms condition compared with 500 ms condition. When the inducer was tilted 3 deg, neither duration gave any effect. For tilts greater than 9 deg, the 10 ms condition always yielded greater effect than the 500 ms condition. However, tilts of less than 9 deg gave no significant difference between durations. In the second study, we looked for similar effects of duration in hue-shift type simultaneous color contrast (cf. Klauke & Wachtler, 2015). We chose all our colors from the equiluminant cone-contrast space whose origin was the equal-energy white (20 cd/m2). Results from experiments using unique yellow as a target hue suggest that the unique-yellow shift was strongly enhanced by briefly flashing the stimulus. Results suggest the existence of universal mechanisms that enhance the difference across visual features between neighboring regions, which work only for briefly presented targets.

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26.3032 **Luminance-contrast properties of texture-shape and of texture-surround suppression of contour-shape** Elena Gheorghiu[1](elena.gheorghiu@stir.ac.uk), Frederick Kingdom[2]; [1]University of Stirling, Department of Psychology, Stirling, Scotland, United Kingdom, [2]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal, Canada

Aim: Contour shape processing is selective to luminance polarity (Gheorghiu & Kingdom, 2006, Vis.Res) and surround textures inhibit the processing of contour shapes (Gheorghiu & Kingdom, 2014, Vis.Res). Energy models of texture processing suggest that textures are not selective to luminance polarity (Malik & Perona, 1990). Here we investigate the nature of first-order inputs to texture-shape and texture-surround suppression by examining whether texture-shape itself and texture-surround suppression of contour shape are selective to luminance-polarity and the magnitude of luminance contrast. Method: To test for luminance-polarity selectivity, textures and contours were constructed from strings of elongated Gaussian blobs that were either 'bright' or 'dark'. To test for selectivity to the magnitude of luminance contrast, textures and contours were constructed from strings of Gabors. Observers adapted to pairs of either sinusoidal-shaped textures made of a series of contours arranged in parallel or single contours that differed in shape-frequency, and the resulting shifts in the apparent shape-frequencies of texture-test or contour-test pairs were measured. Texture-surround adaptors consisted of a central contour and a surround made of parallel contours. We compared the after-effects between: (a) texture-adaptors and tests of same versus different luminance polarity; (b) texture-surround/central-contour adaptors of same versus different luminance polarity (or magnitude of luminance contrast), with contour-tests of same luminance-polarity (or magnitude of luminance contrast) as central-contour adaptor. Results: (i) Texture-shape processing in textures made of elongated Gaussian blobs is selective for luminance-polarity. (ii) Texture-surround suppression of contour-shape processing shows weak selectivity for luminance polarity. (iii) Texture-surround suppression of contour-shape is stronger for equal-in-contrast center and surround, and more prominent for higher than lower surround-to-center contrast ratios. Conclusion: Texture-shape processing depends on on-off luminance polarity channel interactions and texture-surround suppression of contour shape is selective to both polarity and the magnitude of luminance contrast.

26.3033 **Visual analysis of shape assayed with synthetic textures** Jonathan Victor[1](jdvicto@med.cornell.edu), Syed Rizvi[1], Mary Conte[1]; [1]Brain and Mind Research Institute, Weill Cornell Medical College

Algorithmically-defined visual textures provide a way to analyze computations performed in early vision. In this approach, image sets are synthesized that contain independent, controlled variation of several types of local features. The method therefore allows for a characterization of processing of individual feature types and how they interact – something difficult to accomplish with natural images. Here we extend this strategy from elementary visual features to shape. The starting point is our texture-based analysis of contrast, edge, and corner. Here, we used binary textures: each check was black or white according to an algorithm that controlled the one-, two-, three-, and four-point statistics within 2x2 neighborhoods of checks. To extend this idea to elements of shape, we replace the uniformly black or white checks by tiles containing curved segments. The tiles are designed so that where they meet, they form continuous contours. This construction produces an image with extended shapes, whose characteristics are controlled by the underlying binary texture. Specifically, manipulating the two-point and higher-order statistics of this underlying texture produces new textures with curvilinear contours and varying amounts of convex and non-convex shapes. These new textures are balanced for lower-level features such as the length, orientation, and curvature of individual segments. To use these stimuli to analyze texture segmentation based on shape, we asked subjects (N=6) to perform a 4-AFC texture segmentation paradigm, adapted from previous studies. Textures containing isolated circles were more readily segregated than textures containing the equivalent amount of curved segments, but combined in a way that did not produce isolated shapes. Further, simple circles were a stronger segmentation cue than more complex shapes. Because of the construction of the textures from identical sets of tiles, the superiority of circles could not be explained on the basis of the curvature of local segments.

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26.3034 **Mental rotation performance with and without eye movements** Bernard Gee[1](geeb@wcsu.edu), Maura Gissen[2]; [1]Psychology Department, Western Connecticut State University, [2]Counseling Psychology, University of Denver

Visuospatial reasoning is the ability to generate, retain, retrieve, and transform visual images (Lohman 1993). This visual behavior allows us to understand and navigate our physical environment, and in doing so, use mental rotation, which is the ability to visualize an object at various viewpoints (Shepard & Metzler 1971). While it has been established that eye movement patterns correlate with visuospatial performance (Just & Carpenter 1976; Mast & Kosslyn 2002), this was the first study which examined mental rotation without eye movements. Human subjects (n=48) performed a mental rotation task by viewing paired geometrical shapes (Peters & Battista 2008) oriented at three possible disparity angles (50, 100, 150 deg) from one another, and deciding whether they were identical or not. A total of six blocks of 60 trials each were presented. Participants alternated blocks of free viewing with eye movements, and holding their gaze on a central fixation point. Proportion correct and trial response times were measured. Overall, subjects were consistently more successful, but slower, at the task using eye movements than without. During free viewing, proportion correct decreased across disparity angles, and reaction times were static. Without eye movements, both proportion correct and reaction times peaked at the intermediate disparity angle (100 deg), and decreased for the two extreme disparities. These findings indicated that free viewing is important for mental rotation, but at the expense of time. During covert viewing, reaction times also increased with accuracy except for the greatest disparity angle (150 deg). Resolving large orientation disparities between objects may require the utilization of eye movements, since accuracy was close to chance without them and subject reports were in line with this result. Therefore, fixed gazed viewing was more sensitive to task difficulty. This conclusion has further emphasized the importance of eye movements during mental rotation.

Acknowledgement: 2014-2015 CSU-AAUP Grant

26.3035 **Identifying separate components of surround suppression during contrast perception in human subjects** Michael-Paul Schallmo[1](schallmo@uw.edu), Scott Murray[1]; [1]Department of Psychology, University of Washington

Surround suppression is a well-known phenomenon in which the response to a visual stimulus is diminished by other stimuli in the surrounding context. This effect is observed in neural responses in areas such as primary visual cortex, and also manifests in visual contrast perception. Studies in animal models have identified at least two separate mechanisms that may contribute to surround suppression: one that is monocular and resistant to contrast adaptation, and another that is binocular and strongly diminished by adaptation. The current study was designed to investigate whether these two mechanisms exist in humans and if they can be identified psychophysically using eye-of-origin and contrast adaptation manipulations. In addition, we examined the prediction that the monocular suppression component is broadly tuned for orientation, while suppression between eyes is narrowly tuned. Our results confirmed that when center and surrounding stimuli were presented dichoptically (in opposite eyes), suppression was orientation-tuned. Following adaptation in the surrounding region, no dichoptic suppression was observed, and monoptic suppression no longer showed orientation selectivity. These results are consistent with a model of surround suppression that depends on both low-level and higher-level components. This work provides a method to assess the separate contributions of these components during spatial context processing in human vision. Finally, we consider the possible neural substrates for these suppression components, including both cortical and pre-cortical mechanisms.

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26.3036 **Correcting the spatial non-uniformity and viewing angle dependency of an LCD monitor** Jakob Thomassen[1](jakob.thomassen@crsltd.com), Caterina Ripamonti[1]; [1]Cambridge Research Systems Ltd

Improvements in the characteristics of Liquid Crystal Displays (LCDs) are making this technology increasingly popular for vision science experiments. However, the effects of viewing angle dependency are still inferior to that of Cathode Ray Tube (CRT) technology, which have traditionally been used for presenting computer-controlled visual stimuli. Here we show how an LCD monitor can be calibrated to dramatically improve its spatial uniformity and how to compensate for its viewing angle dependency when the location of the observer is known and their position held constant. We first characterised the non-uniformity of the LCD by taking a series of measurements at different locations perpendicular to the screen. These measurements were then used to calculate coefficients for a model of the spatial non-uniformity of the screen. To test the calibration model, we made nine evenly spaced measurements perpendicular to the screen (3x3 grid) and found that the Michelson contrast fell below 0.02. However, this performance would only hold true if the visual angle subtended by the monitor was smaller than 30 degrees in the horizontal direction, beyond which the non-Lambertian characteristics of the LCD affect its light output. To compensate for a wider range of viewing angles subtended by the LCD, we characterised the dependency of angles in the horizontal, vertical and oblique directions. These data were then combined with the data from the perpendicular measurements to produce a model that corrects for both viewing angle dependency and spatial uniformity when the observer's location is known.

Object Recognition: Categories, models and neural correlates

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

26.3037 **Object categorization performance modeled using multidimensional scaling and category-consistent features** Michael Hout[1](mhout@nmsu.edu), Justin Maxfield[2], Arryn Robbins[1], Gregory Zelinsky[2]; [1]New Mexico State University, [2]Stony Brook University

The ability to categorize objects is a ubiquitous human behavior that, like many aspects of cognition, is accomplished so rapidly as to seldom enter consciousness. Yet somehow an instance of a basset hound is classified as a family pet, a dog, or an animal, and not a cat or duck or desk. Our work addresses the complex visual similarity relationships within and between categories that make possible this fundamental cognitive behavior. We studied these similarity relationships using two complementary approaches: 1) Multidimensional Scaling (MDS) data obtained from human observers; and 2) Category-Consistent Features (CCFs), the important features of a target category, computationally-defined as the high-frequency and low-variability features found across images of category exemplars (Maxfield et al., VSS2015). Participants provided spatial similarity ratings for 144 objects (from 4 superordinate-level categories, each with 4 nested basic-level categories, and 3 nested subordinates). Ratings were then subjected to MDS analysis, which successfully recovered the subordinate, basic, and superordinate-level category clusters within our stimuli. We then identified "centroids" for categories at each level of the hierarchy, and used the distance of each category centroid from the target or lure (an object from the same parent category as the target) to predict the performance of other participants (leave-one-out method) in a categorical search task. We found that behavioral similarity ratings reliably predict categorical search performance (e.g., time to fixate a target exemplar or lure), and did so better than a random model. These findings also align with CCF-model performance, which defines similarity computationally, based on the visual features that are shared among category exemplars. Taken together, our findings suggest that human-based and computational methods of quantifying visual similarity offer important and complementary insights into how similarity impacts people's ability to represent object categories across a hierarchy, and use these representations to conduct search.

26.3038 **Generating the features for category representation using a deep convolutional neural network** Chen-Ping Yu[1](cxy7452@gmail.com), Justin Maxfield[2], Gregory Zelinsky[1,2]; [1]Department of Computer Science, [2]Department of Psychology

What are the visual feature representations of common object categories and how are these representations used in goal-directed behavior? Our previous work on this topic (VSS2015) introduced the idea of category-consistent features (CCFs), those maximally-informative features that appear both frequently and with low variability across category exemplars. Here we extend this idea by using a deep (6-layer) convolutional neural network (CNN) to learn CCFs. The four convolutional layers corresponded to visual processing in the ventral stream (V1, V2, V4, and IT), with the number of filters (neurons) at each layer reflecting relative estimates of neural volume in these brain areas. The CNN was trained on 48,000 images of closely-cropped objects, divided evenly into 48 subordinate-level categories. Filter responses (firing rates) for 16 basic-level and 4 superordinate-level categories were also obtained from this trained network (68 categories in total), with the filters having the least variable and highest responses indicating a given category's CCFs. We tested the CNN-CCF model against data from 26 subjects searching for targets (cued by name) from the same 68 superordinate/basic/subordinate-level categories. Category exemplars used for model training and target exemplars appearing in the search displays were disjoint sets. A categorical search task was used so as to explore model predictions of both attention guidance (time between search display onset and first fixation of the target) and object verification/detection (time between first fixating the target and the present/absent target judgment). Using the CNN-CCF model we were able to predict, not just differences in mean guidance and verification behavior across hierarchical levels, but also mean guidance and verification times across individual categories. We conclude that the features used to represent common object categories, and the behaviorally-meaningful similarity relationships between categories (effects of hierarchical level) can be well approximated by features learned by CNNs reflecting ventral stream visual processing.

Acknowledgement: This work was supported by NSF award IIS-1161876 to GJZ.

26.3039 **Dichotomy Versus Continuum: Evidence for a More Complex Agency Model of Visual Object Categorisation** Erika Contini[1,2](erika.contini@mq.edu.au), Mark Williams[1,2], Tijl Grootswagers[1,2], Erin Goddard[1,2], Thomas Carlson[1,2]; [1]Perception in Action Research Centre (PARC) and Department of Cognitive Science, Faculty of Human Sciences, Macquarie University, [2]ARC Centre of Excellence in Cognition and its Disorders, Macquarie University

The neuroscience of visual object categorisation has revealed a number of spatially and temporally distinct neural representations of objects in the human brain, though has yet to sufficiently account for what factors or features the brain uses to delineate object subcategories. The animate/inanimate dichotomy is well established as an overarching organisational principle. Some have further suggested a representational continuum, specifically that groups objects based on similarities between biological classes (Connolly et al., 2012; Sha et al., 2014). While the latter may account for variability between animate subcategories, there has been limited evaluation of category structure within the inanimate domain. The neural representations of inanimate objects that exhibit animate features (e.g. human/animal-like robots or toys) have yet to be fully explored, and raise questions as to the potential contribution of more complex factors related to agency and experience which are known to influence human perception of these types of objects (Gray, Gray, & Wegner, 2007). Using magnetoencephalography and multivariate pattern analyses, we mapped the time course of object categorisation for 120 images across 12 object categories (6 animate, 6 inanimate). We evaluated the efficacy of both dichotomy and continuum models of object categorisation, as well as newly generated models based on agency and experience. Our results indicate that the presence of faces best accounts for the representation of object categories around the time of peak decoding (peak at ~180ms post stimulus onset), whereas later representations (peak at ~245ms) appear best explained by more complex factors related to the object's perceived similarity to humans. These findings call for a re-evaluation of models of object categorisation, to include more complex human-centered factors relating to agency and experience in the emerging representation of object categories in the human brain.

26.3040 **Probabilistic Atlas of Category-Selective Regions of Ventral Temporal Cortex** Michael Barnett[1](michaeab@stanford.edu), Kevin Weiner[1], Jyothi Guntupalli[2], Jesse Gomez[3], Vaidehi Natu[1], Anthony Stigliani[1], Kalanit Grill-Spector[1,3,4]; [1]Psychology Department, Stanford University, [2]Department of Psychological and Brain Sciences, Dartmouth College, [3]Neurosciences Program, Stanford University School of Medicine, [4]Stanford Neurosciences Institute, Stanford University

Researchers use functional magnetic resonance imaging (fMRI) to localize functional regions of interest (fROI) in ventral temporal cortex (VTC) that preferentially respond to particular categories such as faces, bodies, places, and words. In many cases, this fMRI localizer cannot be obtained, for example, in patient populations. The goal of this project is to generate a probabilistic functional atlas that can be used to predict the location of fROIs in people's brains based on anatomy alone. Twelve subjects were scanned with fMRI using a localizer showing images of characters, bodies, faces, places, and objects (Stigliani et al., 2015). From these data, six fROIs in VTC from each subject were identified: mFus-faces/FFA-2, pFus-faces/FFA-1, CoS-places/PPA, OTS-bodies/FBA, pOTS-characters/VWFA-1, and mOTS-characters/VWFA-2 based on significantly higher fMRI activation for preferred vs. non-preferred stimuli. fROIs were projected to each subject's cortical surface, cortex-based aligned to a common cortical surface of the FreeSurfer average template, and then density maps were created, reflecting the percentage overlapping subjects for each fROI at each vertex of the average template. Probabilistic ROIs (pROIs) were created by thresholding these maps at 33% to remove outliers and then eliminating vertices shared by multiple fROIs (Figure 1). To validate the spatial predictability of pROIs, we implemented a leave-one-out cross-validation procedure. Our results show that place-selective fROIs are consistently predicted (78%±2%) in independent subjects and more so than face-, body- and character-selective fROIs (main effect of ROI, $F(5,64)=20.2$; $p< 10\text{-}6$). Thus, predictability is best for fROIs that have the most consistent localization relative to cortical folding (Weiner et al. 2014; Grill-Spector & Weiner 2014). We are evaluating additional methods such as hyperalignment (Haxby et al., 2011) that may improve the predictability of this functional atlas.

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26.3041 **Information processing dynamics in human category-selective fusiform gyrus** Avniel Ghuman[1,2,3](ghumana@upmc.edu), Yuanning Li[1,2,3], Elizabeth Hirshorn[4], Michael Ward[1], Julie Fiez[2,4,5], Mark Richardson[1,2]; [1]Neurological Surgery, University of Pittsburgh, [2]Center for the Neural Basis of Cognition, Univeristy of Pittsburgh, [3]Program in Neural Computation, University of Pittsburgh, [4]Learning Research and Development Center, University of Pittsburgh, [5]Psychology Department, University of Pittsburgh

The fusiform gyrus contains category-selective patches that are critical for visual recognition with damage to these patches leading to category-selective impairments in object recognition, such as acquired alexia and prosopagnosia. However, many gaps remain in our understanding of the dynamic role the fusiform plays in contributing to multiple stages of category-specific information processing. To assess the information processing dynamics of the fusiform, here we report results from 7 subjects with intracranial electrodes placed directly on word selective (2 subjects) or face selective (5 subjects) fusiform gyrus (the "visual word form area [VWFA]" and "fusiform face area [FFA]" respectively). Specifically, we use multivariate machine learning methods in conjunction with multiple face and word processing paradigms to uncover common neurodynamic information processing principles of category-selective fusiform gyrus. The results show strong decoding accuracy ($d' = 1.5\text{-}3.5$ across subjects) for faces and words in the FFA and VWFA respectively, first becoming statistically significant between 50-100 ms and peaking between 150-200 ms. Next we examined the dynamics of within category decoding. For words significant decoding was seen in both subjects between approximately 150-300 ms wherein visually similar words could not be decoded from one another, but dissimilar words could be decoded (organized by orthographic similarity). There was a later phase between approximately 250-500 ms where even orthographically similar words could be significantly decoded from one another (individual-level representation). For faces significant expression-invariant decoding was seen in each subject in the same 250-500 ms time frame. The neural response for faces was organized by facial feature similarity, emphasizing the role of the eyes and mouth in face individuation. Taken together, these results suggest a multi-stage information processing dynamic wherein the representation in category-selective fusiform gyrus evolves from a coarse category-level representation to an invariant and highly detailed individual representation over the course of 500 ms.

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26.3042 **Representational similarity analysis of category-related recognition-memory signals in the human medial temporal lobe** Anna Blumenthal[1](ablumen@uwo.ca), Bobby Stojanoski [1], Chris Martin[2], Rhodri Cusack[1,3], Stefan Köhler[1,4]; [1]University of Western Ontario, [2]University of Toronto, [3]University of Cambridge, [4]Baycrest Centre

Neuropsychological studies in patients and functional neuroimaging work have established that perceptual representations of complex objects in the visual ventral stream are shaped by semantic category membership. Whereas the categorical structure of these representations has been well characterized in the context of perceptual tasks, much less is known about the organization of corresponding memory signals, specifically in the medial aspects of the temporal lobe (MTL), which includes the perirhinal, parahippocampal, and entorhinal cortices, as well as the hippocampus. These structures have distinct patterns of connectivity to occipito-temporal and ventrolateral temporal cortex, and are thought to be important for both visual perception and memory. In the current study, we used high resolution fMRI, in combination with multi-voxel pattern analysis, to examine representational similarities in distributed patterns of activity in the MTL during memory judgements for images of real-world objects. Specifically, participants performed a continuous recognition memory task on visually presented objects from 12 different categories, which were matched for recognition accuracy. On each trial, their task was to determine whether the object presented was new (1st presentation) or had been encountered before (2nd presentation). Our primary goal for the analyses of the fMRI data was to characterize representational similarities in memory signals, i.e. in differences between activity patterns for the 1st as compared to 2nd presentation of items from the various categories examined. Preliminary results show evidence for category-specific representations across the different structures that comprise the MTL. This suggests that category structure is differentially preserved in recognition-memory signals in MTL structures, offering support for the notion that its influence extends beyond perceptual representation.

26.3043 **Differential representation of category and task information across high level visual cortex and ventro-lateral prefrontal cortex** Lior Bugatus[1,2](liorbu@stanford.edu), Kevin Weiner[1,2], Kalanit Grill-Spector[1,2]; [1]Department of Psychology, Stanford University, Stanford, CA, [2]Stanford Neuroscience Institute, Stanford University, Stanford, CA

The human brain contains functional networks across lateral occipital (LOTC), ventral temporal (VTC), and ventro-lateral prefrontal (VLPFC) cortices that are involved in processing visual categories. However, it is unknown how the combination of cognitive task and visual category affects the neural responses of regions within these networks. Here we addressed this question by scanning 12 subjects using fMRI while they viewed stimuli from five categories: faces, bodies, houses, cars, and pseudo-words. While viewing these categories, subjects performed one of three tasks in separate runs across the same session, with task order counterbalanced across subjects: Oddball: subjects detected a randomly presented phase-scrambled image. Working memory: subjects indicated whether a stimulus repeated after an intervening image. Selective attention: subjects viewed superimposed images from two categories, attended to one stimulus category, and reported when the attended stimulus was flipped upside-down. Using a data-driven approach, we examined distributed neural responses in anatomically defined regions of interest for each subject (Fig. 1A). We generated representational similarity matrices containing pairwise correlations between distributed responses across runs for each combination of task and visual category (Fig. 1B). Results show that distributed responses in LOTC and VTC are highly similar for the same visual category across tasks ($F(2,132) = 41.47$, $p < 0.001$). In contrast, distributed responses in VLPFC were similar for the same cognitive task across different visual categories ($F(2,132) = 6.44$, $p = 0.002$; Fig. 1C). Across subjects, a regression model ($R2 > 0.45$ for all subjects and ROIs) showed that the category effect was twice as large as the task effect in LOTC and VTC (βcategory=0.332+/-0.029, βtask=0.17+/-0.017), whereas in VLPFC the task effect was five times larger than the category effect (βcategory=0.057+/-0.009, βtask=0.281+/-0.04). Taken together, our data reveal a differential representation of category and task information across high-level visual cortex and VLPFC.

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26.3044 Category learning causes a stable advantage for category-relevant shape dimensions during a task requiring attention to all dimensions: ERP evidence Michael Dieciuc[1](MichaelD180@gmail.com), Nelson Roque[1], Jonathan Folstein[1]; [1]Department of Psychology, Florida State University

Objects differ along a number of different dimensions (e.g., shape, color, size) but only some of these dimensions are relevant for successful categorization. Learning to categorize cars along relevant dimensions can lead to stable changes in the visual system. These changes involve stretching psychological space to make exemplars differing in relevant features more dissimilar than exemplars differing in irrelevant features. This selective stretching of psychological space along relevant dimensions is known as dimensional modulation. Here, we (1) provide further evidence that category learning causes stable dimensional modulation, observable in tasks where learned categories are irrelevant and (2) probe the time course of these effects. Participants learned to categorize morphed cars according to a relevant shape dimension while ignoring an irrelevant shape dimension. After four sessions of categorization training, EEG was recorded during a task requiring the identification of a single target car. Importantly, learned category boundaries were not relevant to this task so that participants had to attend to both relevant and irrelevant shape dimensions. The critical comparison was between two types of non-target cars: those that differed from the target along category-irrelevant dimensions and those that differed along category-relevant dimensions. If category learning caused stable dimensional modulation, then non-targets with irrelevant differences should appear more target-like than non-targets with relevant differences, eliciting more target-like ERPs. As predicted, targets elicited a larger selection negativity, a postero-lateral component sensitive to detection of target features, than non-targets and non-targets with irrelevant differences elicited a larger selection negativity than non-targets with relevant differences. Interestingly, category-relevance of perceptual differences did not modulate the P300, a later decision related component. Overall, the results suggest that category learning causes stimuli with relevant differences to be perceived as less similar than stimuli with irrelevant differences, even when attention is directed to both kinds of features.

26.3045 The effect of category learning on attentional feature selection: Selection negativity and N250 likely reflect different processes Jonathan Folstein[1](jonathan.r.folstein@gmail.com), Shamsi Monfared[1], Trevor Maravel[1]; [1]Psychology Department, Florida State University

Subordinate level category learning recruits neural resources associated with perceptual expertise, including the N250 component of the ERP, a postero-lateral negative wave maximal between 230 and 330 milliseconds. The N250 is a relatively late visual ERP and could plausibly be driven by attention to the features of categorized objects. Indeed, it has a latency and scalp distribution similar to the selection negativity (SN), an ERP component long known to be sensitive to attentional selection of target features. To clarify sensitivity of the N250 to attention and to more generally investigate the effect of category learning on attentional modulation of learned features, we independently manipulated subordinate level category learning and target detection in a speeded paradigm designed to optimally elicit the SN and accompanying selection positivity (SP). Participants first practiced categorizing a set of artificial animal stimuli over two training sessions and then performed a speeded target detection task on trained and untrained stimuli while ERPs were recorded. Targets appeared on 20% of the trials and each non-target stimulus shared between 0 and 4 features with the target. The paradigm elicited a robust posterior SN and anterior SP with amplitudes strongly related to the number of target features contained in the stimulus. Trained stimuli elicited a significantly larger N250 than untrained stimuli. The SN and N250 effects were additive, with all levels of target similarity equally affected by training, and had slightly different scalp distributions. Furthermore, frontal electrode cites where the SP was observed showed no sign of a training effect. The results suggest that 1) the N250 and SN have different sources and 2) at the very least, the learning-induced N250 indexes a different attentional subprocess from the target-induced SN and could be unrelated to attention.

26.3046 Decoding the informative value of early and late visual evoked potentials in scene categorization Bruce Hansen[1](bchansen@colgate.edu), Michelle Greene[2], Catherine Walsh[1], Rachel Goldberg[1], Yanchang Zhang[1]; [1]Department of Psychology and Neuroscience Program, Colgate University, Hamilton, NY, [2]Computational Sciences, Minerva Schools at KGI, San Francisco, CA

Recent advances in information-based brain imaging data analysis (e.g., neural decoding) have provided deep insight into the spatiotemporal dynamics of how the brain processes and ultimately represents objects and scenes (e.g., Cichy et al., 2014; Ramkumar, et al., 2015 respectively). However, the spatiotemporal dynamics involved in the neural representation of scene category have only been explored with a handful of categories, and therefore can only speak to coarse categorization of exemplars from disparate scenes. The time-coarse of neural signals underlying fine-grained scene categorization therefore remains an open question. Here, we sought to extend information-based analysis of neural temporal dynamics involved in scene categorization via neural decoding of visual evoked potentials (VEPs) measured through Electroencephalography (EEG). Specifically, we examined the informational value of different VEPs with respect to their relative ability to signal for fine-grained scene category information. Participants viewed 2,250 exemplars of full-color scene images (matched for luminance and color contrast) drawn from 30 different categories while having their brain activity measured through 128-channel EEG. The stimuli subtended 14° x 14° of visual angle, and were presented to the fovea for 500ms. Participant attention was maintained with a super-ordinate categorization task. All VEPs were decoded with a linear multiclass support vector machine (SVM) classifier applied within a 40ms sliding window at each time point at each electrode. The results revealed that the foveal C1 component (peaking between 90-100ms post-stimulus onset) was best able to discriminate between all 30 scene categories, with the bilateral P1 and central-frontal N2 being a distant second. All later components contained very little, if any, category information. Given that the foveal C1 has been argued to be dominated by cortical generators within striate cortex, the current results imply that early low-level visual signals may serve to define the boundaries between different fine-grained scene categories.

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26.3047 Representational dynamics: the temporal evolution of neural population coding in nonhuman primate inferior temporal cortex Marieke Mur[1](marieke.mur@mrc-cbu.cam.ac.uk), Andrew Bell[1,2,3], Nicholas Malecek[3], Elyse Morin[3], John Duncan[1], Nikolaus Kriegeskorte[1]; [1]Cognition and Brain Sciences Unit, Medical Research Council, [2]Department of Experimental Psychology, University of Oxford, [3]Lab of Brain and Cognition, National Institutes of Mental Health

The dynamics of inferior temporal (IT) object population representations is not well understood. Here we analyze single-unit recordings from monkey IT to investigate the emergence of representational distinctions and the degree to which they can be explained by computational features of different complexities (GIST and the layers of a deep neural network). Single-unit activity was recorded from 989 neurons in the inferior bank of the superior temporal sulcus of two adult macaques passively viewing 100 grayscale object images from five categories (faces, body parts, fruit, objects, indoor scenes) presented for 300 ms at fixation at 5 degrees visual angle (Bell et al., 2011). We analyzed activity patterns across all visually responsive neurons with dynamic representational similarity analysis. Both within- and between-category distinctions arise early, with the earliest distinctions evident 50-80 ms after stimulus onset. Between-category distinctions tend to peak earlier (130-160 ms after stimulus onset) than within-category distinctions (about 10-50 ms later), possibly reflecting the fact that between-category pairs of exemplars are also visually more distinct. When removing the effect of low-level visual similarity by regressing out the pattern of distinctions predicted by the GIST model, the within-category distinctions are entirely explained for most of the categories. However, between-category distinctions remain substantial and significant at larger latencies after stimulus onset. We also used the layers of a deep neural net (Krizhevsky et al. 2012) to explain the representational dissimilarities as a function of time with a linear model containing one dissimilarity predictor for each layer. Results revealed that the high-level semantic layer 7 explained distinctions arising late (around 130-200 ms), while lower layers explained both early and late distinctions. Taken together, these results suggest that the IT code reflects both visual similarity and category distinctions and that the latter require some recurrent processing to emerge.

Acknowledgement: Medical Research Council

26.3048 Observing Prefrontal Cortex Activity During Rule-Based and Information-Integration Category Learning Pooja Patel[1](pooja@knights.ucf.edu), Audrey Hill[1], Urvashi Nayee[1], Denise Garcia[1], Corey Bohil[1]; [1]Department of Psychology, University of Central Florida

A prominent neuropsychological theory of category learning called COVIS (for Competition between Verbal & Implicit Systems) posits that separate brain systems compete to learn a classification rule. The prefrontal cortex (PFC) tends to mediate learning of verbalizable category rules while the basal ganglia underlies learning of non-verbalizable category rules. Because the systems compete, the explicit system may persist in seeking a classification rule even when the implicit system is better suited to the task. As a result of this prediction, we expect higher PFC activity when learners attempt to use a verbalizable rule when a nonverbalizable rule is appropriate. When a verbalizable rule is appropriate, we expect PFC activity to decline once the rule has been discovered. The current experiment replicates earlier studies that observed explicit (verbalizable) or implicit (nonverbalizable) classification rule learning. Functional near-infrared spectroscopy (fNIRS) was used to measure hemodynamic changes in the PFC as participants learned over three blocks of training trials. Participants completed either a rule-based (RB, explicit) or information-integration (II, implicit) learning task. Participants classified simple 2D stimuli: lines that varied in orientation and length from trial to trial. Across blocks response accuracy increased in both conditions. Participants in the II condition showed greater PFC activation than those in the RB condition, particularly near the end of training. Dividing participants into early and late learners (based on block 1 training performance), late learners in the II condition again displayed greater PFC activation than in the RB task (amplifying the trend found when all participants were included in the analysis). Focusing on the II condition, late learners showed significantly greater activation than early learners in blocks 2 and 3 (who had already learned the rule) implying that they were still attempting to discover a verbalizable classification rule later in training. These results support our COVIS-based predictions.

Perception and Action: Action influences perception

Saturday, May 14, 2:45 - 6:45 pm

Poster Session, Pavilion

26.4001 Temporal-generality and viewpoint-specificity of sensory predictions during action Daniel Yon[1](danieljamesyon@gmail.com), Clare Press[1]; [1]Department of Psychological Sciences, Birkbeck, University of London

Sensory predictions made by the motor system during movement are likely to facilitate adaptive interaction with the sensory world. Recently, it has been suggested that agents may use the same sensorimotor models to anticipate the consequences of their own movements and to predict matching behaviours in others (i.e., imitative reactions). Under this hypothesis, underlying sensory models should exhibit considerable generality across time and viewpoint, as the actions of others are typically observed at delays in the order of seconds and from different perspectives. Here we examine this hypothesis by investigating how action influences the processing of visual outcomes presented at different viewing perspectives and with varied action-effect delays. We measured the perceived brightness of sensory outcomes of movement, given recent findings that events congruent with prediction are perceived more brightly than those unpredicted. In a series of psychophysical experiments, participants performed finger abductions (index or middle) while observing congruent or incongruent movements performed by an avatar hand. The observed lifted finger 'flashed' at one of seven intensities (10-70 % increase in local brightness) 50 ms after observed movement onset before being replaced by a comparison stimulus. Participants judged which event appeared brighter, and the point of subjective equivalence (PSE) was derived from the modelled psychometric function. Experiment 1 revealed that when hands are viewed from a first-person perspective, congruent action outcomes are perceived to be brighter, irrespective of the action-effect delay (0 -3600 ms). In contrast, Experiment 2 revealed no effects of action congruency when hands are viewed from a third-person perspective. These results suggest that predictive processes during action may operate with greater generality than previously thought. However, despite generalising across time, the underlying mechanisms may still be ill-suited to anticipating the behaviour of others given their lack of generalization across viewpoint.

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26.4002 Contextualizing action-specific effects: How much influence does action information have on perceived speed? Zach King[1](kingzac@rams.colostate.edu), Jessica Witt[1]; [1]Colorado State University

Action-specific perception researchers claim that action information causes a difference in perception of task relevant stimuli. One example of this is the pong paradigm in which participants attempt to block a ball and rate the speed of the ball. When participants use a small paddle, the ball is rated as moving faster than when they use a large paddle (hard vs. easy blocking conditions). One question that arises from the claim that action affects perception is "how much does action affect perception?" The current research explores this question in the pong paradigm by pitting action information against an optical cue for motion using the method of constant stimuli. Over the course of 3 experiments and 1 replication, participants had to block a 1 cm diameter ball moving between 26.2 cm/s and 74.2 cm/s with a 1.86 cm paddle or a 9.28 cm paddle against a background of moving dots which either moved in the same direction (+) or opposite direction (-) of the ball. The results of these experiments demonstrate that the effect of reducing the paddle length by 7.42 cm is equivalent to changing the background motion of the dots from -19.13 cm/s to 19.13 cm/s. Both background motion against the target and the small paddle made the ball appear approximately 4 cm/s faster (8.3% increase in speed) compared to background motion moving in the same direction and the large paddle respectively. These results contextualize how big of an impact action information has on vision. In baseball, an 8% increase in the speed of a fastball is achieved by shifting pitcher grip, and this change can be the difference between a strike or not. Action information does have a practically significant impact on motion perception.

26.4003 That's so far! Experienced hikers also overestimate distances on a hill Marcos Janzen[1,2](mjanzen@colostate.edu), Nate Tenhundfeld[1], Jessica Witt[1]; [1]Cognitive Psychology, Colorado State University, [2]Departamento de Psicologia, Universidade Federal do Rio Grande do Sul, BR

According to the action-specific perception account, spatial perception is affected by the energetic costs required to perform an action. For example, hills require more energy to traverse than flat ground, so distances on a hill are overestimated relative to distances on flat ground. This is known as the distance-on-hills effect. However, previous research has also shown that perception may be scaled to one's ability to act. Factors that affect ability and thus influence perception include body size, body control and coordination, energetic potential, and the challenges of the task. In the current experiment, we examined if hiking experience would alter the distance-on-hill effect. Our hypothesis was that people with more experience walking up hills would be able to resist this bias in spatial perception. Thus, people with greater experience would show a reduced, if not eliminated, bias to see distances on hills to be farther than distances on the flat. Participants visually matched distances on a hill to distances on flat ground in VR. As expected, participants overestimated the distances on the hill, judging the cone on the hill as being closer than the cone on the flat, indicating that distances on a hill look farther. Participants also answered a survey on hiking experience. The factor analysis of this survey demonstrated an adequate single factor solution, and had an acceptable Cronbach's alpha of 0.764. Therefore, we examined whether hiking experience related to the distance-on-hills effect. Hiking experience produced no change in the distance-on-hill effect, which was significant for low and high experience hikers. Results suggest that the distance-on-hills effect is robust and perceptually stable. Even for those with lots of experience on hills, the effect remains the same. A hallmark of many perceptual phenomena is that prior experience plays little to no role. The distance-on-hills effect shares this feature.

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26.4004 Three's Company: Energetics' Effect on Perception as Shown with Blind Walking, Visual Matching, and Verbal Estimates Nathan Tenhundfeld[1](nlt4au@rams.colostate.edu), Jessica Witt[1]; [1]Colorado State University

A growing body of research has suggested that distances on hills appear farther than distances on the flat, likely because of the greater amount of energy required to walk that same distance on a hill. However, there has been concern that these effects are due to experimental demand. Previous distance-on-hill studies have used verbal estimates, an inherently biased method of estimation. Therefore, we tested this effect with a visual matching and blind walking measure; these measures have been shown to more accurately and reliably characterize distance perception. In separate studies, the distance-on-hills effect was found when using blind walking

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and visual matching. To compare across measures, we ran a third study in which participants estimated distances to cones placed at 7, 8, and 9 meters on both a hill and flat ground for verbal and blind walking estimates. For the visual matching, participants moved a reference cone on the flat until the distance between themselves and the cone on the flat was the same as the distance between themselves and the cone on the hill (also placed at 7, 8 and 9 meters). The distance-on-hill effect emerged using all three measures. Convergence across measures, especially those touted for their accuracy, suggests a common, underlying process, which is theorized to be perception as opposed to response-specific biases. By collecting multiple responses for each measure, we were also able to assess the reliability of this action-specific effect across each measure. We found that the visual matching task produced the best reliability. Reliability in measures is critical for future research assessing individual differences, which can help in furthering our understanding about the mechanisms that drive these perceptual distortions, such as interoceptive attunement.

Acknowledgement: NSF

26.4005 Ease of action toward a target enhances orientation discrimination during motor preparation

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Perception and action interact in nearly every moment of daily life. Research demonstrates that performing an action toward an object can impact perceptual processing. For example, changes in orientation are detected more efficiently when relevant actions (i.e., grasps) are directed toward the target. Furthermore, it has been also shown that ease of action can enhance liking of a target stimulus; how ease of action influences visual perception, however, is lesser known. To address this question, right-handed participants were instructed to perform a grasp toward a Gabor patch, while simultaneously performing an orientation change detection task. On a given trial, the Gabor patch appeared on either the left or right side of the screen and was oriented to be ± 45º from vertical. In addition, the Gabor patch could slightly change its orientation during action preparation. Because all subjects were right-handed, ease of grasping was easier and fluent towards the right-tilted object (+45 °). As a control, participants also performed the same orientation change detection task with pointing or perception. These served as a baseline for when an action is performed with no relevance to orientation (pointing) or when no action is performed. We found that participants performed best on the orientation discrimination task when grasping movements were prepared for right-tilted targets (+45 °). Therefore, we suggest that ease of action enhances perceptual sensitivity, but this is only the case when action features are relevant.

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26.4006 The influence of action production kinematics on identification of others' affective states

Rosaana Edey[1](redey01@mail.bbk.ac.uk), Iroise Dumontheil[1], Jennifer Cook[2], Clare Press[1]; [1]Birkbeck College, University of London, [2]Birmingham University

Different affective states have previously been shown to have specific kinematic signatures, for example, sad movements tend to be slow, and angry movements are fast and accelerated. We likely use these kinematic signatures to help us to perceive affective states in others. If so, our models of the kinematic-affective state correspondence may be based upon experience of our own actions. We therefore predicted that first, altering the kinematic properties of affective movements should reduce the perceived intensity of the correct affective state, and second, perceived intensity would be influenced by participants' own action kinematics. To test these hypotheses, affect perception was measured by asking typical adult participants to rate on a visual analogue scale the extent to which happy, angry, sad and neutral point-light walkers expressed happiness, anger and sadness. The affective animations were either un-manipulated (100%), or were altered to bring the velocity closer to that of the neutral walker (66%, 33% and 0%, with 0% being equivalent to neutral velocity). The kinematics of the participant's leg were also measured during a walking task. In confirmation of our first hypothesis, participants' intensity ratings of the correct affective state decreased linearly as the velocity information pertaining to affective states was removed. Second, there was a linear correlation between participants' own walking kinematics and their perceptual judgements. Faster walkers gave the slower affective states (sadness) higher intensity ratings than the faster affective states (anger), and the slower walkers showed the opposite pattern. Therefore, we may rate the intensity of an affective state according to its kinematic difference from our own neutral movement kinematics. These results suggest that kinematics communicate important information about our affective states, and that individuals calibrate their perception of others' affective states relative to their own reference kinematics.

26.4007 Does the motor system contribute to action recognition in social interactions?

Stephan de la Rosa[1](stephan.delarosa@gmail.com), Ylva Ferstl[1], Heinrich Bülthoff[1,2]; [1]Department of Perception, Cognition, and Action Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [2]Department of Brain and Cognitive Engineering, Korea University, Seoul, South Korea

It has been suggested that the motor system is essential for various social cognitive functions including the perception of actions in social interactions. Typically, the influence of the motor system on action recognition has been addressed in studies in which participants are merely action observers. This is in stark contrast to real social interactions in which humans often execute and observe actions at the same time. To overcome this discrepancy, we investigated the contribution of the motor system to action recognition when participants concurrently observed and executed actions. As a control, participants also observed and executed actions separately (i.e. not concurrently). Specifically, we probed the sensitivity of action recognition mechanisms to motor action information in both unimodal and bimodal motor-visual adaptation conditions. We found that unimodal visual adaptation to an action changed the percept of a subsequently presented ambiguous action away from the adapted action (adaptation aftereffect). We found a similar adaptation aftereffect in the unimodal non-visual motor adaptation condition confirming that also motor action information contributes to action recognition. However, in bimodal adaptation conditions, in which participants executed and observed actions at the same time, adaptation aftereffects were governed by the visual but not motor action information. Our results demonstrate that the contribution of the motor system to action recognition is small in conditions of simultaneous action observation and execution. Because humans often concurrently execute and observe actions in social interactions, our results suggest that action recognition in social interaction is mainly based on visual action information.

26.4008 Action experience drives visual processing biases near the hands

Laura Thomas[1](laura.e.thomas@ndsu.edu); [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Observers experience affordance-specific biases in visual processing for objects within the hands' grasping space. Although these biases presumably reflect the visual system's adaptive sensitivity to behavioral contexts, it is unclear the extent to which long-term evolutionary pressures versus short-term learning experiences tune visual cognition to facilitate action. I investigated the hypothesis that altered vision near the hands is a result of experience-driven plasticity. Participants performed global-motion-detection and global-form-perception tasks under hands-near and hands-far conditions. In the hands-near condition, participants adopted a posture in which the backs of their hands faced the display—a posture placing stimuli outside of the hands' typical grasping space. In the hands-far condition, participants rested their hands in their laps. Participants then engaged in a brief training session in which they repeatedly grasped and moved an object by securing it between the backs of their hands, essentially learning a new power grasp affordance. Following this training session, participants again performed the motion-detection and form-perception tasks under the hands-near and hands-far conditions. Prior to training, performance on both tasks was similar in the hands-near and hands-far conditions. However, following training, participants' performance on the motion-detection task improved substantially when stimuli were viewed near the backs of the hands, while performance in all other conditions remained relatively unchanged. These results point to the mechanism responsible for altered vision near the hands, suggesting that biases are plastic and facilitate processing of visual information relevant to learned grasp affordances: training with an unconventional power grasp enhanced temporal, but not spatial, sensitivity for stimuli viewed near the backs of the hands.

Acknowledgement: Google Faculty Research Award

26.4009 Action-Based Compression of Spatial Memory for Individual and Nested Environments

Andrew Clement[1](aclemen3@nd.edu), James Brockmole[1]; [1]Department of Psychology, University of Notre Dame

Physically interacting with all objects in an environment leads to underestimation of inter-object distances, as well as the overall size of the environment (Thomas et al., 2013). Here, we assessed whether interacting with a subset of objects could compress the remembered spatial layout of all objects, both in individual and nested environments. In Experiment 1, half of participants visually inspected five objects in a room, while the other half picked up and manipulated these objects. Participants then estimated the distance between each pair of objects from memory. Participants who manually inspected the objects recalled shorter object-pair distances than those who passively viewed them (t(76) = 2.07, p = .042), revealing compressed memory for the spatial layout. In Experiment 2, participants manually or visually inspected the same five objects, but passively viewed five additional objects located around the periphery of the room (no spatial organization was apparent from this layout). Participants who manually inspected the central five objects recalled shorter object-pair distances for all objects in the room, while those passively viewed the objects did not (F(1,59) = 5.36, p = .024). Thus, interacting with only a subset of objects compressed spatial memory for the entire environment. In Experiment 3, a physical boundary between the central and surrounding objects was added, creating two nested environments. Manual inspection did not affect memory for object-pair distances (F(1,48) = .304, p = .584), suggesting that the influence of action is limited to a single environment. In this case, biases in spatial memory for objects in adjacent and nested environments (McNamara, 1986; Huttenlocher et al., 1991) played a greater role in shaping participants' memory of the layouts. For example, participants in Experiment 3 recalled shorter overall distances than those in Experiment 2, and biased their memory for spatial locations away from environmental boundaries.

26.4010 **Action potentiates conceptual links between words and pictures** Blaire Weidler[1](blaire.weidler@gmail.com), Richard Abrams[1]; [1]Psychological and Brain Sciences, Washington University in St. Louis

Recent research has demonstrated that action can have a profound influence on perception. For example, preparing or executing an action toward an object can subsequently alter the perception of basic features of the object such as color, shape, or size. Here for the first time we show that an arbitrary action directed toward an object can influence perception of stimuli that share only a conceptual relationship with the acted-on object. More specifically, in two experiments participants either made an action towards (pressed the space bar) or viewed a word. Next, a search array appeared in which participants searched for a left or right arrow (while ignoring a distracting vertical or horizontal arrow). Both the target and distractor arrows were superimposed on images. Although irrelevant to the visual search task, one image always represented the word that had been seen earlier. Participants responded faster when the target was on that image (presumably due to word-picture priming) even though it was not predictive of the target location. Importantly, in both experiments this word-picture priming effect was enhanced following an action towards the word. Thus, these results show that an action towards an object results in prioritization in the visual system not only of basic perceptual features of the object (such as color and shape), but of conceptual ones as well.

26.4011 **The effects of action on continuous flash suppression** Wolfgang Einhäuser[1,2](wolfgang.einhaeuser-treyer@physik.tu-chemnitz.de), Peter Veto[2], Immo Schütz[1]; [1]Chemnitz University of Technology, Physics of Cognition, [2]Philipps-University Marburg, Neurophysics

The interaction between action and visual perception is bi-directional: not only does vision guide most of our actions, but a growing number of studies suggest that our actions can in turn directly affect perceptual representations. The degree of action-perception congruency required to evoke such direct effects of action on perception is, however, debated. To address this issue, we used a continuous flash suppression (CFS) paradigm. A dynamic Mondrian pattern was presented to one eye, a horizontally drifting vertical grating to the other. In the main experimental condition ("coupled condition") the drift velocity of the grating was controlled by the observer through turning a manipulandum, such that the grating represented the front face of a virtual drum attached to the manipulandum. The control conditions included a visual-replay condition (no movement, but same visual stimulus) and a de-coupled motor condition (movement, but visual stimulus based on a different trial). In all conditions, observers were instructed to try and perceive the grating for as long as possible and to report by pressing a button whenever they achieved clear visibility. To overcome the obvious confound of non-veridical report, we validated report by measuring the observers' optokinetic nystagmus (OKN), which follows the grating if and only if it is visible. Our data show that the grating becomes visible more frequently and persists longer in the coupled condition than in the visual-only and de-coupled conditions. This shows that action exerts a direct effect on perception in CFS and that this effect requires visual-motor congruency. Intriguingly, congruency aids the appearance of the stimulus from suppression; that is, congruency may also reference action to a stimulus that is suppressed from awareness. Our results provide further evidence for shared representations between action and perception, and suggest that those may partially operate below visual awareness.

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Motion: Biological motion

Saturday, May 14, 2:45 - 6:45 pm

Poster Session, Pavilion

26.4012 **An integrated model for the shading and silhouette cues in the perception of biological motion.** Leonid Fedorov[1](leonid.fedorov@cin.uni-tuebingen.de), Martin Giese[1]; [1]Center for Integrative Neuroscience, HIH, UKT, University of Tuebingen

In absence of stereo and texture cues the perception of biological motion can show multistability, where different walking directions can be attributed to the same physical stimulus (Vangeneugden 2012, Vanrie 2004, 2006). This bistability disappears for walkers that consist of shaded volumetric elements, where the disambiguation depends on the light-source direction. No neural models exist that account for this multi-stability of biological motion perception, or its dependence on shading cues. METHODS: We extended an established neural model for biological motion perception (Giese & Poggio, 2013) by two essential mechanisms: (i) A two-dimensional neural field that consists of snapshot neurons that are selective for keyframes of actions with different preferred views. The dynamics of this recurrent neural networks reproduces the multi-stability of biological perception. (ii) A new hierarchical pathway that processes intrinsic shading cues, independent of contours generated by the silhouette of the walker. RESULTS: The model reproduces the observed bistability of biological motion perception, perceptual switching, and its dependence on adaptation. We are able to reproduce the disambiguation by additional shading cues, and demonstrate that the robustness of processing of such internal shading cues is improved by the novel shading pathway. CONCLUSION: Body motion perception integrates multiple cues, including surface shading. Straight-forward extensions of existing neural models can account for these effects.

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26.4013 **Serial dependence in perception of biological motion** Wesley Chaney[1](wchaney07@gmail.com), Alina Liberman[2], David Whitney[3]; [1]Vision Science Graduate Group, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley, [3]Psychology, University of California, Berkeley

We experience the visual world as a continuous and stable environment of objects and events, despite rapidly changing retinal input due to eye movements and visual noise. One proposed mechanism for maintaining this apparent stability is serial dependence of visual perception: our current visual experience is biased toward what we have perceived in the recent past, facilitating information processing in an autocorrelated world. Recent studies have shown that perception of orientation and facial identity are biased toward previously seen stimuli (Fischer and Whitney, 2014; Liberman et al., 2004). We investigated whether this same perceptual bias occurred in the judgment of biological motion, specifically heading direction of point light walkers. Accurate perception of heading direction of point light walkers requires integration of information over time into a dynamic structural representation based on prior assumptions about how the local 2D information is generated by a familiar 3D form of a walker. The purpose of the current experiment is to extend previous investigation of serial dependence in static 2D images to the realm of dynamic representations. Subjects viewed a single walker presented in the periphery and followed by a mask. Subjects were then asked to adjust a second walker to match the direction of heading of the target walker. Subjects consistently made errors biased toward the direction of the target walker presented on the previous trial when the heading directions were similar across the two contiguous trials. Our results show that serial dependence can occur even for perception of stimuli that require integration of complex information over time and prior assumptions about the structure of complex objects in the world.

26.4014 **Is the motor contagion effect an artifact of eye movements?** Merryn Constable[1,2](merryndconstable@gmail.com), Tiffany Lung[1], John de Grosbois[1], Luc Tremblay[1], Jay Pratt[2], Timothy Welsh[1]; [1]Faculty of Kinesiology and Physical Education, University of Toronto, [2]Department of Psychology, University of Toronto

The 'motor contagion' effect manifests when a participant performs one action while simultaneously observing an action performed by another person; observing an incongruent action relative to a congruent action results in an increase in spatial displacement along the orthogonal plane to the participant's intended movement. Motor contagion is often cited as an example of motor interference produced by the activation of motor neurons associated with the observed action that compete with the target action. In the typical motor contagion paradigm, little attention has been given to the complexities of how an individual's eye movement may influence action execution. Indeed, experimenters often instruct their participants to follow the hand of the actor with their eyes while completing the task. It is well known that hands follow eyes; therefore, this instruction could have a large impact on the way motor 'contagion' manifests. Thus, we investigated if concurrently executed eye movements could explain the motor contagion effect. Participants made horizontal arm movements while observing an actor making either vertical (incongruent) or horizontal (congruent) movements under three conditions: no instruction, instruction to maintain fixation on a central cross, or instruction to follow the actor's hand with their eyes. The eye and hand movements of the participants were recorded. Movement variability in the secondary axis was larger in the incongruent than congruent movement conditions only in the 'follow' condition. These data indicate that motor contagion-like effects may be an artifact of simultaneously executed eye movements. We conclude that, at least in this case, an actor's actions are not 'contagious' unless the participant has an existing propensity to follow an actor's actions with their eyes.

26.4015 **Effects of movement-shape inconsistencies on perceived weight of lifted boxes.** Sophie Kenny[1](kenny.s@queensu.ca), Nikolaus Troje[1,2,3]; [1]Department of Psychology, Queen's University, Kingston, [2]Department of Biology, Queen's University, Kingston, [3]School of Computing, Queen's University, Kingston

Perceiving the weight of a lifted object from visual displays of the lifting person is a non-trivial task. Runeson and Frykholm (1981), who worked with biological motion point-light displays, attributed the ability to estimate the weight of a lifted box to what they called the Kinematic Specification of Dynamics. The KSD assumes that dynamics are inferred from observed kinematic patterns by means of an internal model of the relations between body shape and body kinematics. Using MoSh, that is, Motion and Shape Capture from Sparse Markers (Loper, Mahmood, & Black, 2014) we created animated, life-like human avatars from surface motion capture data of performers lifting light and heavy boxes. For some of our stimuli, we then combined the body shape of one lifter with the kinematics of another to create hybrid lifters. In the consistent condition, stimuli were generated using the shape and movement from the same performer. In the low- and high- inconsistency conditions, the shape and movements of the stimuli were taken from different performers; however, in the former, the shape and motion were from different performers with similar body masses, and in the latter, shape was matched with motion from individuals with dissimilar body masses. Participants estimated the perceived weight of the lifted box. Results showed that participants could discriminate between box weights, although they slightly overestimated their real weight. However, we did not find the expected dependency of internal consistency. Further studies will examine the degree to which larger inconsistencies are detectable, and in which domains internal consistency matters.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

26.4016 **Negative Affect Impairs the Working Memory Capacity of Biological Motion** Zaifeng Gao[1](zaifengg@gmail.com), Fangfang Qiu[1], Rende Shui[1], Shulin Chen[1], Mowei Shen[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

Biological motion (BM) broadly refers to the movements of animate entities. It contains abundant social information, therefore, recognizing and understanding biological motion is of great survival significance to human beings. A few recent studies have begun to reveal the underlying mechanisms of holding BM information in working memory, for instance, by showing that BM information is stored independently from color, shape, and location. However, no study so far has investigated the interaction between affect and holding BM in working memory. The current study explored this issue by exploring the impact of happy, neutral, and negative affect in holding BM in working memory. In Experiment 1, we required participants to remember 2-5 BM stimuli in a change-detection task after inducing different affective states. We found that working memory capacity of BM was significantly dropped in the negative affect condition than in the happy or neutral affect condition, and no difference was found between the latter two. The reduction of BM capacity led by the negative affect was further confirmed in Experiment 2, by using an EEG index of mu-suppression which could track the load of BM information stored in working memory. Finally, in Experiment 3 we examined whether negative affect would improve the precision of BM in working memory, and found that the BM precision was kept stable between neutral and negative affect. Taking together, the current study suggests that negative affect reduces working memory capacity of BM; yet the precision of BM in working memory was not affected.

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26.4017 **Spatiotemporal dissimilarity influences the perceptual discriminability of deceptive and non-deceptive throwing** Fabian Helm[1,2](fabian.helm@sport.uni-giessen.de), Séamas Weech[1], Jörn Munzert[2], Nikolaus Troje[1]; [1]Department of Psychology, Queen's University, Kingston, Canada, [2]Department of Psychology and Sport Sciences, Justus-Liebig-University Giessen, Germany

The internal simulation of observed actions is thought to play a crucial role in the process of recognizing action intentions of others (Jeannerod, 2001). In many situations, performers attempt to manipulate this process in order to deceive another. For example, competitive athletes may try to convince opponents that one action is being performed, while another is actually carried out. It has been shown that the visual system is sensitive to the intentions of deceptive movements, although prediction accuracy is reduced (e.g. Grèzes et al., 2004). Real and deceptive actions typically display a degree of spatiotemporal dissimilarity in terms of motion trajectories and temporal dynamics of the movement kinematics. Currently there is no research that examines how these spatiotemporal dissimilarities influence the discriminability of deceptive movements for novice and expert observers. We addressed this question in the context of handball throws. We motion captured deceptive and non-deceptive throwing movements of novice and elite handball field players and used these to generate realistic 3D avatars. In a perceptual task, we asked novice and expert handball players to judge whether observed throws were either deceptive or non-deceptive. The results show that both groups were highly sensitive to deception in throws. Expert observers were significantly better than novices at discriminating throws from both elite and novice performers. In general, discriminability was directly related to spatiotemporal dissimilarities between deceptive and non-deceptive throws. Elite performers produced deceptive throws that were highly similar to non-deceptive throws, resulting in higher misclassifications by observers. We interpreted these findings in the context of prediction errors resulting from internal simulation of kinematically similar deceptive and non-deceptive throws. The higher sensitivity to deception displayed by experts points towards superior action simulation based on stored motor representations for practiced actions, resulting in fewer prediction errors. Future neurophysiological studies should directly address this interpretation.

Acknowledgement: DFG IRTG 1901 "The Brain in Action"

26.4018 **The Frozen Body Effect: Bodies in motion are more flattering than bodies frozen in time** Malerie McDowell[1](mcdmg-17@rhodes.edu), Yoonkeong Chi[1], Jason Haberman[1]; [1]Rhodes College

The Frozen Face Effect (FFE) is the phenomenon in which a video of a face in motion is perceived as more flattering that the video's constituent static images (Post, R.B., Haberman, J., Iwaki, L., & Whitney, D., 2012). This speaks to the perceptual 'normalcy' of viewing faces in motion as opposed to faces frozen in time (i.e., photographs). In the current set of experiments, we sought to determine whether this effect is unique to facial processing, per se, or if it is also present in other stimulus categories, such as bodies, that is, a Frozen Body Effect (FBE). If motion were the mitigating factor in the FBE, we would expect a static image of a body in motion to be significantly less appealing than when seen in the context of a video. If, however, the FFE were specific to face processing, we would expect no differences between the ratings of the videos and static images. To examine this, we asked participants to rate a set of 25 videos of bodies in motion (without visible faces) along with the 30 constituent frames of each video. Images and videos were interleaved and randomly presented and rated on a 'flattery' scale from 1-7, with 1 being least flattering. Replicating the original FFE, we found that participants rated videos of bodies in motion as significantly more flattering than the corresponding still images, suggesting that the FFE generalizes beyond face perception. Inverting the images and videos did not disrupt the FBE, further supporting the importance of natural motion, and not holistic object configuration, in judging aesthetic appeal. Only when the natural motion was disrupted by scattering the order of the video frames was the FBE mitigated.

26.4019 **Does action recognition suffer in a crowded environment?** Laura Fademrecht[1](laura.fademrecht@tuebingen.mpg.de), Judith Nieuwenhuis[1], Isabelle Bülthoff[1], Nick Barraclough[2], Stephan de la Rosa[1]; [1]Human Perception, Cognition and Action, Max Planck Institute for Biological Cybernetics, [2]Department of Psychology, University of York

In real life humans need to recognize actions even if the actor is surrounded by a crowd of people but little is known about action recognition in cluttered environments. In the current study, we investigated whether a crowd influences action recognition with an adaptation paradigm. Using life-sized moving stimuli presented on a panoramic display, 16 participants adapted to either a hug or a clap action and subsequently viewed an ambiguous test stimulus (a morph between both adaptors). The task was to categorize the test stimulus as either 'clap' or 'hug'. The change in perception of the ambiguous action due to adaptation is referred to as an 'adaptation aftereffect'. We tested the influence of a cluttered background (a crowd of people) on the adaptation aftereffect under three experimental conditions: 'no crowd', 'static crowd' and 'moving crowd'. Additionally, we tested the adaptation effect at 0° and 40° eccentricity. Participants showed a significant adaptation aftereffect at both eccentricities ($p < .001$). The results reveal that the presence of a crowd (static or moving) has no influence on the action adaptation effect ($p = .07$), neither in central vision nor in peripheral vision. Our results suggest that action recognition mechanisms and action adaptation aftereffects are robust even in complex and distracting environments.

26.4020 **Two Equals One: Social Interaction Groups Two Biological Movements as One Unit** Xiaowei Ding[1](psyxwding@gmail.com), Rende Shui[1], Shulin Chen[1], Mowei Shen[1], Zaifeng Gao[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

Human beings are social in nature. Interacting with other people using human body is one of the most important activities and abilities in our daily life. To have a coherent visual perception of dynamic actions and engaging in normal social interaction, we have to store these interactive movements into working memory (WM). However, the WM mechanism in processing these interactive biological movements (BMs) remains unknown. In the current study, we explored the representation format of interactive BMs stored in WM, by testing two distinct hypotheses: (1) each interactive BM can be stored as one unit in WM (integrated unit hypothesis); (b) constituents of interactive BMs are stored separately in WM (individual storage hypothesis). In a change detection task, we required the participants to memorize interactive BMs in which two person were in beating, dancing, dashing, drinking, talking, or conversation. We found that there was no difference between memorizing four interactive BMs (containing eight individual BMs) and four individual BMs, and both performances were significantly lower than remembering two interactive BMs (Experiment 1). In Experiment 2, we further test whether spatial proximity but not social interaction resulted in the results of Experiment 1, by introducing a random-pair condition in which the social interaction was destroyed but spatial proximity still existed. We found that participants remembered equally well between two interactive BMs and two individual BMs, and both performances were significantly better than remembering two random-pair BMs; there was no difference between memorizing two random-pair BMs and four individual BMs. Together, these results suggest that an interactive biological movement containing two individual moments are stored as one unit in WM.

Acknowledgement: National Natural Science Foundation of China (31271089 3157111961431015)

26.4021 **Biological motion distorts size perception** Peter Veto[1](veto@staff.uni-marburg.de), Wolfgang Einhäuser[1,2], Nikolaus Troje[3]; [1]Philipps-University Marburg, Neurophysics, [2]Chemnitz University of Technology, Physics of Cognition, [3]Queen's University Kingston, Department of Psychology

Size perception is distorted in several illusions, including some that rely on complex social attributes: for example, people of higher subjective importance are associated with larger size. Biological motion receives preferential visual processing over non-biological motion with similar low-level properties, a difference presumably related to a stimulus' ecological importance. Hence, we asked whether biological motion perception can also lead to size illusions. In each trial, observers (N=16) were simultaneously exposed to an upright and an inverted point-light walker from a frontal view for 250 ms. After disappearance of the walkers, two circles were flashed at their positions. The circles differed in size to varying degrees, and observers were queried to indicate with a non-speeded button press, which of the circles appeared larger. We conducted paired sample t-tests on the parameters of the psychometric curves fitted to response frequencies for upright versus inverted cued targets. We found that the circle at the location of the upright walker was perceived smaller than the circle at the location of the inverted walker ($t(15) = 2.37$, $p < .05$). Our findings introduce a novel illusion: biological motion reduces subsequently perceived size relative to non-biological motion.

Acknowledgement: German Research Foundation, International Research Training Group, IRTG 1901, "The Brain in Action"

3D Perception: Space and mechanisms

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4022 **Implied motion does not generate an internal motion signal for the perception of depth from motion parallax** Shanda Lauer[1](Shanda.Lauer@my.ndsu.edu), Jessica Holmin[1], Mark Nawrot[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Static images taken from an animation of continuous motion contain no real motion information; however these implied motion (IM) stimuli may activate the same brain regions as real motion. Real motion signals, and even motion-aftereffect, when combined with smooth pursuit, produce depth from motion parallax (MP). If IM generates the same neural motion signals as real motion, then IM may generate a percept of depth from MP. In the current study, IM stimuli were produced by placing an image of a human actor, in a running pose, above and below a fixation square. The pose above and below fixation faced opposite directions, generating IM in opposite directions. Observers were required to maintain fixation as the entire MP stimulus translated left or right at 3.1 deg/sec. To titrate IM with real motion, fixed amounts of motion (11 magnitudes: ± 0 – 0.54 deg/sec) were added to the figures. Observers indicated which of the two figures (top or bottom) appeared nearer in depth relative to fixation. The dynamic geometry of MP dictates that the actor translating in the same direction as fixation is perceived nearer. We determined whether IM, in the same or opposite direction as pursuit, influenced the depth phase judgment. In two control conditions, participants made depth phase judgments for MP stimuli that did not contain IM. A psychometric function (PF) for each condition was created by plotting the percentage of "top nearer" responses against each magnitude of real motion. If IM affected perceived depth from MP, the PF would be shifted horizontally away from zero. There was no shift in the PFs in any of the three conditions ($F = 1.95$, $p = 0.16$), indicating that perceived depth sign was not affected by IM. This result indicates that IM is not acting as a real motion signal for MP.

Acknowledgement: NIH Center of Biomedical Research Excellence Grant NIGMS P20 GM103505

26.4023 **The influence of viewing distance, depth range and inter-camera distance on depth perception and preference judgments in complex natural scenes** Rebecca Hornsey[1](rlhornsey@outlook.com), Paul Hibbard[1], Peter Scarfe[2]; [1]Department of Psychology, University of Essex, [2]School of Psychology and Clinical Language Sciences, University of Reading

Binocular cues contribute to the perception of depth, and the sense of realism, in stereoscopic images. The binocular disparities in an image depend on the three-dimensional shapes and locations of objects, the distance from which they are viewed, and the distance between the observer's eyes. We assessed how these factors affect the perception of depth in complex natural scenes. By manipulating the interocular distance used to render stereoscopic images, we varied the depth specified by binocular disparity while all other depth cues were held constant. This allowed us to assess the importance of binocular vision in the perception of depth in naturalistic stimuli. We found that apparent depth increased with increasing simulated interocular distance. This is consistent with the idea that perceived depth in natural images combines information from monocular and binocular cues to estimate depth. We also assessed the apparent quality and realism of depth in the same scenes. It might be predicted that this would be optimal when the simulated interocular distance matched that of the observer, since in this case binocular cues are consistent with the depth specified by monocular cues. However, it might also be predicted that quality would increase with increasing disparity, if this enhances the sensation of stereoscopic depth. Conversely, quality might decrease with increasing disparity, since this creates a conflict between binocular and focus cues. We found that depth quality was greatest when a close-to-natural interocular distance was simulated. However, observers preferred greater simulated interocular distances when the viewing distance was large, and when the depth range in the stimuli was small. These results show that depth quality is highest with images are rendered using a natural interocular distance, but that this is moderated by the distance and depth range in the simulated scene.

Acknowledgement: British Academy MidCareer Fellowship (MD130066) University of Essex Undergraduate Research Opportunities Programme

26.4024 **Sensory cues used to determine 3D world stability** Peter Scarfe[1](p.scarfe@reading.ac.uk), Andrew Glennerster[1]; [1]School of Psychology and Clinical Language Sciences, University of Reading, UK

We have shown that when a simulated room scales in size around a person they remain completely unaware of the scaling, ignoring stereo and motion cues in favour of assumed world stability (Glennerster, Tcheang, Gilson, Fitzgibbon and Parker. 2006). Here we investigated whether this phenomenon is unique to uniform scaling of an environment, or applies to the more general case where objects can move relative to both the observer and one another. Observers were free to move in a simulated environment consisting of checkerboard textured spheres arranged in groups of four (a "quad"). There were 1- 4 quads on different trials. In a two-interval forced-choice experiment, observers identified a sphere (pointing response) which was moved towards or away from them by 2m (matched retinal angle). There were three viewing conditions (1) isolated spheres, (2) pairs of spheres connected by a line "dipole", (3) line dipoles switched between interval one and two to connect the other sphere pair in a quad. Thus, in all conditions, the 3D coordinate information was the same across intervals, however in one condition the scene changed. Performance always deteriorated when more spheres were presented but was unaffected by adding dipoles (condition 2) unless they switched between intervals (condition 3) in which case performance was significantly worse. In follow up experiments, we showed that this degraded performance was near-eliminated if the spheres were visible during movement, and performance dramatically improved when a sphere's changing retinal angle was visible as it moved. If observers had access to the 3D coordinates of the spheres, all of the tasks would have been trivially easy to complete. We conclude that the primary information people used to tell whether the world around them had changed was determined by changes in the cyclopean image.

Acknowledgement: EPSRC

26.4025 **Field of view restriction has response-specific effects on distance judgments** John Philbeck[1](philbeck@gwu.edu), Daniel Gajewski[1], Courtney Wallin[1], Sandra Mihelic[1]; [1]Department of Psychology, The George Washington University

Background: Recently, we found that distance judgments made via blindwalking were larger in outdoor settings than indoors, but only when targets were seen through an aperture that occluded all but the region immediately around the target. Because the visual cues available through the aperture were roughly constant across settings, knowledge about the unseen setting presumably played a role. While shorter walked distances indoors may reflect a genuine perceptual bias associated with this knowledge, participants may simply tend to stop short when walking with walls nearby. Method: To test this, we compared distance estimates (blindwalking) and gestured size estimates--a response not constrained by walls--for indoor targets 2.5 – 5 m distant. Walking showed increased underestimation under aperture-restricted viewing than under unrestricted viewing (M = -20% vs. -7%); size gestures showed a similar pattern (M = -5% vs. 8%). This suggests that there is a perceptual component underlying the effects of aperture-restricted viewing; the physical constraints on walking imposed by the walls does not fully explain the effect. We next compared verbal reports of distance and gestured target size, manipulating setting (indoors / outdoors), under aperture-restricted viewing. This replicated our past blindwalking design, but with two responses not constrained by walls. Results: There were no indoor-outdoor effects on constant errors with either response type. Because we previously found increased undershooting with blindwalking when indoors under similar conditions, the lack of effect here may implicate a residual walking-specific output-related effect: in this view, under aperture-restricted viewing, the indoor setting is assumed to be small, but the aperture conceals the precise boundaries and this elicits conservative walking. Conclusions: Taken together, the results indicate that indoor/outdoor effects under aperture-restricted viewing—a condition that closely matches the visual cues available across settings--may reflect interactions between perceptual and output processes.

Acknowledgement: NEI: R01EY021771

26.4026 **Can spatial biases be eliminated through learning?** Zhi Li[1](zli1@zju.edu.cn), Yongchun Cai[1], Ci Wang[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

The perceived spatial layout is not veridical (or accurate). It has been shown that perceived slant is exaggerated, perceived in-depth distance is foreshortened, and even perceived 2D orientation/angle is distorted. What causes these spatial biases? Are they simply due to the lack of experience? The present study examined whether the spatial biases could be eliminated by experience. A simple form of spatial bias, the horizontal vertical illusion (HVI), was studied. Experiment 1 used a size estimation task, in which the participants judged whether the actual size of a horizontal (or vertical) line shown on the center of a CRT screen was longer or shorter than that indicated by a size label (i.e. "4 cm", "6 cm", or "8 cm") shown on the upper left corner of the screen. The results showed that the perceived size of 2D lines was substantially underestimated, and the underestimation was stronger for the horizontal lines. This size-anisotropy in perceived 2D lines well predicted the magnitude of HVIs obtained from a size comparison task with the same group of participants, which indicated that the HVI is due to perceptual biases in perceived size. Experiment 2 examined whether the HVI can be eliminated by training (i.e. by providing feedback) in the size estimation task. The results showed that, after training, participants' performance in the size estimation became pretty accurate; however, the HVIs obtained from the size comparison task remained intact. These results suggested that the perceptual biases in perceived 2D size were not affected by the training in the size estimation task, and the fact that the size estimation became more accurate after training was probably due to cognitive learning rather than perceptual learning.

26.4027 **Are 2D and 3D location equally prioritized in object processing?** Nonie Finlayson[1](nonie.j@gmail.com), Julie Golomb[1]; [1]Department of Psychology, The Ohio State University

Location information plays a special role in visual processing. This has been demonstrated in a number of ways, including a new paradigm called the "spatial congruency bias" (Golomb et al., 2014), which shows that two objects sharing the same location are more likely to be judged as having the same feature/identity. However, this bias has only been tested for 2D location: here we adapted the spatial congruency bias paradigm to ask if 2D and 3D location are equally prioritized in object processing. In Experiments 1 and 2 we examined if 2D and depth location bias judgments of each other. In Experiments 3 to 5 we examined if 2D and depth location bias color judgments. Participants judged whether two sequentially presented objects had the same or different depth location (Experiment 1), 2D location (Experiment 2), or color (Experiments 3-5), while ignoring any irrelevant dimensions. We found that 2D location biased both color and depth judgments, with objects at the same 2D location more likely to be judged as the same color/depth. In contrast, depth did not bias 2D location or color judgments. Specifically, we found that although depth cued by binocular disparity appeared to bias color judgments, this may have been driven by low level disparity cues, as color judgments were also biased by vertical disparity, which does not cause a depth percept. Depth cued by occlusion did not bias color judgments. We propose that depth information does not bias features, but that eye-dependent 2D location information does. In conclusion, depth information appears to be less fundamental for visual processing than 2D location, and object processing is biased by low-level 2D location information, before depth location is computed from retinal images.

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26.4028 **A 3D database of everyday objects for vision research** Paul Hibbard[1,3](phibbard@essex.ac.uk), Peter Scarfe[2], Rebecca Hornsey[1], David Hunter[3]; [1]Department of Psychology, University of Essex, [2]School of Psychology and Clinical Language Sciences, University of Reading, [3]School of Psychology and Neuroscience, University of St Andrews

The study of natural image statistics has helped us to understand the way that the visual system encodes and processes information. In the case of depth and distance, a number of databases exist that allow these statistics to be assessed in natural scenes. These databases tend to focus on scenes containing relatively distant objects. We have developed a database of 3D models of individual objects, and a method for combining these, to create scenes in which these objects are distributed in near space. This approach complements existing datasets, and allows us to assess depth statistics for objects within reachable distance. This range is particularly relevant for understanding human binocular depth perception. We created 3D models of everyday objects using a laser scanner and colour camera. We then computer-rendered scenes, using OpenGL, in which these objects were randomly positioned on a virtual table top in front of the modelled observer. We used this approach to create binocular image pairs with corresponding ground truth distance data. This method has a number of advantages. Firstly, it avoids the need to co-register visual and depth information, and eliminates uncertainty about the locations of the cameras. Sec-

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ondly, it allows the parametric variation of important variables such as the inter-camera separation, depth of field and lighting conditions. Thirdly, it allows the creation of multimodal stimuli, since the objects can be rendered both visually and haptically. This level of control is useful for both statistical analysis and the creation of stimuli for psychophysical experiments.

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26.4029 **Local Cues for Half-Occlusion Detection in Stereo-Images of Natural Scenes** Johannes Burge[1](jburge@sas.upenn.edu); [1]Department of Psychology, University of Pennsylvania

In natural scenes, most points are binocularly visible, but many are half-occluded. Half-occlusions occur because the left eye can image regions of the scene around the left side of objects that the right eye cannot and vice versa. Half-occluded points contribute to Da Vinci stereopsis and are useful for segmenting images into different depth planes. However, there is no consensus for how the visual system accomplishes this feat. We examine half-occlusion detection performance for three local cues in natural images. First, we obtained a large database of calibrated stereo images with precisely co-registered laser range data. Next, we developed procedures to i) identify half-occluded points and ii) sample binocularly visible (corresponding) points with arcsec precision. We randomly sampled 100,000 points from the dataset and computed the interocular difference of three image properties in the immediate neighborhood (0.25deg) of the sampled point: local luminance, contrast, and contrast-contrast (change in contrast). Then, we conditioned these interocular differences on whether they corresponded to half-occluded or binocularly visible points; the likelihood of a half-occlusion increases with interocular difference. To quantify performance, we computed the log-likelihood ratio, used it as a decision variable, and computed d-prime. As expected, interocular contrast difference is a strong predictor of half-occlusions (76% correct; d'~=1.4). Perhaps more surprising, interocular luminance difference is an equally good predictor of half-occlusions (76% correct; d'~=1.4); interocular contrast-contrast difference is not much worse (71%; d'~=1.2). Further, all three statistics are largely independent. We estimated the joint conditional probability distributions of the cues and repeated the procedure above. When all three cues are used, performance climbs to (~84%; d'~=2.0). Thus, three very simple local cues can provide surprisingly good information about whether a given point is half-occluded or binocularly visible. Future work will examine how to optimally combine local cues across space.

26.4030 **Estimating local surface attitude from 3D point cloud data.** Alexander Muryy[1](a.muryy@soton.ac.uk), Wendy Adams[2], Erich Graf[3], James Elder[4]; [1]Centre for Vision and Cognition, University of Southampton, UK, [2]Centre for Vision Research, York University, Toronto, Canada

The Southampton-York Natural Scenes (SYNS) dataset consists of LiDAR range and image data captured from a variety of natural and built environments. One of our goals is to use the dataset to relate the ecological statistics of 3D surfaces to human perception of surface attitude. A local planar fit at a 3D point in the dataset can be estimated from an eigen-decomposition of a k-neighbourhood of surrounding points. One challenge is to determine the optimal local scale, k; smaller scales produce noisier estimates, while larger scales lead to over-smoothing. We designed and evaluated two algorithms for adaptively selecting the optimal local scale. The first algorithm uses unsupervised leave-one-out cross-validation (XVAL). For each scale k we fit k planes using k-1 points and measured error of fit as the average distance of the left-out point from the plane. The XVAL method assumes white sensor noise. However, in many sensors, including our own Leica P20, internal post-processing produces correlated noise. To address this problem, we evaluated a second, supervised method based on null hypothesis testing (NHT). Under the NHT approach, the surface is assumed to be locally planar unless there is strong evidence to the contrary. In the NHT training phase, we used a planar reference surface to measure the maximum observed mean deviation of points from fitted planes as a function of scale k and distance. In the estimation phase, this function provides an upper bound on the expected deviation for a locally planar surface; we select the maximum k that does not exceed this bound. Both methods tend to select smaller scales for bumpy surfaces and larger scales for flat surfaces. However, by taking noise correlations into account, the NHT method produces more reliable and more accurate surface attitude estimates for a range of different environments.

26.4031 **Rich-cue virtual environments can be disadvantageous when discriminating navigation models** Ellis Gootjes-Dreesbach[1](E.L.Gootjes-Dreesbach@reading.ac.uk), Lyndsey Pickup[1], Andrew Fitzgibbon[2], Andrew Glennerster[1]; [1]School of Psychology & Clinical Language Sciences, University of Reading, [2]Microsoft Research Ltd

We have shown that, in a sparse cue environment, small changes in scene layout can significantly affect the precision with which observers can return to a previously-viewed location (Pickup, L.C., Fitzgibbon, A.W. and Glennerster, A. (2013) Biological Cybernetics, 107, 449-464). The scene consisted of three very long vertical poles viewed from one of three locations, with stereo and motion parallax cues available. The participants were transported (virtually) to a different part of the scene and had to return to the original location. The spread of errors varied systematically with the configuration of poles in this sparse scene. There was no floor or background and no informative size cues (the poles were one pixel wide), so the only visual cues for determining scene layout and observer location were the changing angles (and binocular disparity) between the poles as the observer moved. We have developed a model of navigation based on 3D reconstruction of the scene (Pickup et al, 2013) and a quite different type of model based on matching 'view-based' parameters at the estimated 'home' location (Pickup, L.C., Fitzgibbon, A.W., Gilson, S.J., and Glennerster, A. (2011) IVMSP Workshop, 2011 IEEE 10th 135-140). Here, we make an explicit comparison between the two types of models. Likelihoods of the data fall within the distribution of likelihoods sampled from the view-based model but not from the 3D reconstruction model. We have repeated the navigation experiment in a rich-cue environment so that the same vertical poles are now viewed in a room with a floor, furniture and paintings on the wall. The variance of homing data and the dependence on scene structure is significantly reduced in the rich-cue condition making it much harder to discriminate rival models.

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26.4033 **The large-scale horizontal-vertical illusion produced with small objects** Frank Durgin[1](fdurgin1@swarthmore.edu), Zhi Li[2]; [1]Department of Psychology, Swarthmore College, [2]Department of Psychology and Behavioral Sciences, Zhejiang University

The comparison of large-scale vertical objects with frontal horizontal extents produces a horizontal-vertical illusion (HVI) that is quite large (e.g., 20% rather than 6%; Chapanis & Mankin, 1967) and that is yoked to the orientation of the ground plane (Klein et al., in press). Here we tested whether a large-scale HVI could be induced in small-scale objects simply by forcing observers to compare their 3D size rather than their 2D projections. We first (N=40) established that we could reproduce both the large-scale and small-scale HVIs using a stereoscopic virtual environment: Horizontal and vertical poles of 4.5-7.5 m viewed at simulated distances of 20-30 m showed HVIs of up to 18% using a method of adjustment, whereas reducing the lengths and viewing distances by a factor of 5 produced HVIs of only about 6% for the same configurations. We next conducted two manipulations to dissociate two different theories of the large-scale effect. To test the Yang et al. (1999) hypothesis that the perceived scale of the object determines the size of the HVI, we embedded normal-size (N=7) or 1/5 scale (N=7) moving avatars into the small-scale scene to modify the perceived sizes of the objects. Although explicit estimates of pole heights were appropriately increased when the avatars were miniatures, this did not increase the HVI, which remained small (M = 6%). However, we were able to produce a large-scale HVI (M=15%) with the same small-scale objects by simply presenting the horizontal and vertical poles at different distances along the ground so that comparisons between 3D sizes rather than 2D projections were required. These results support the hypothesis that the large-scale HVI is due to 20% greater perceptual expansion in angular elevation than in azimuth (Klein et al., in press). The large-scale HVI depends on the visual information used to evaluate length and height.

Acknowledgement: NEI R15 EY021026

26.4034 **Holistic and analytic observation of the vertical-horizontal illusion: the way of looking at things alters percept of line length** Masahiro Ishii[1](m.ishii@scu.ac.jp); [1]Sapporo City University

A figure that consists of two lines forming an inverted T shape creates a geometrical illusion. The vertical line appears to be longer than a horizontal line of equal length (the vertical-horizontal illusion). People mostly judge the line length from the holistic appearance of the figure, concerning its proportions. There is more than one way to judge the length of the vertical line relative to the length of the horizontal line. An analytic observation is a possibility. One, for instance, can mentally rotate and translate the horizontal line to compare with the vertical line side-by-side in the plane

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of representation. In the present study, we examine whether an analytic observation modulates the line length judgment of the VH illusion. An experiment, using the method of adjustment technique, was conducted to measure the point of subjective equality, where the vertical line seemed to be the same length as the horizontal line. 168 observers participated. Each participant performed two trials in a row: one trial by a holistic observation and the other by an analytic observation. The viewing distance was 50 cm and the horizontal line subtented 5.7 degree constantly. For the holistic observation, they overestimated the length of the vertical line an average of 16.8%. For the analytic observation, by contrast, they overestimated the length an average of 4.9%. The illusion was significantly smaller with the analytic observation than with the holistic observation. One theoretical accounts of the VH illusion is the perspective theory, a vertical line is perceived as receding from the observer, whereas a horizontal line is perceived to lie in the display surface. It may be assumed that the 2D mental rotation counteracts the illusory 3D recession of the vertical line.

26.4035 Size constancy is not accomplished in the early stage of visual processing

Juan Chen[1](jchen737@uwo.ca), Melyvn Goodale[1], Irene Sperandio[2]; [1]The Brain and Mind Institute, The University of Western Ontario, London, Ontario, Canada, [2]School of Psychology, University of East Anglia, Norwich, UK

Within a certain range, people's perception of the size of an object will not change with viewing distance, even though the size of the image projected on the retina changes. This is called size constancy. To achieve size constancy, it is necessary to compensate for changes in retinal image size with distance by using a range of depth cues. When and where depth cues act on the representation of size is still unclear. Here we used ERPs to address this question. A black disk, which could be small or big, was presented on a white background at a near or far viewing distance. The near-small and far-big conditions had the same retinal size. The near-small and far-small conditions had the same perceived size, as did the near-big and far-big conditions. Participants were tested in a dimly-lit room with all depth cues available. They were asked to indicate whether the disk was small or big regardless of distance (Experiment 1) or to detect the onset of the disk (Experiment 2). In both experiments, we found that within the first 150 ms after stimulus onset, the ERP waves of the two conditions that had the same retinal size overlapped. After 150 ms, the ERP waves grouped and synchronized according to their physical size (i.e., perceived size) regardless of distance. Because both C1 (which is thought to reflect the response of V1) and P1 (which is thought to reflect the response of extrastriate visual cortex) emerge within the first 150 ms, our results suggest that size constancy is computed after 150 ms in higher-order visual areas beyond V1 and extrastriate cortex. Thus, the size-constancy related fMRI activation that has been observed in V1 may depend on back-projections from these higher-order areas.

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26.4036 Size-distance Paradox in an Optical Tunnel

Seokhun Kim[1](seok.kim@uconn.edu), Michael Turvey[1]; [1]Department of Psychology, University of Connecticut

Introduction The phenomenon of size-distance paradox has been poorly understood in terms of its factors. We investigated this issue with an optical tunnel, an apparatus for systematically controlling nested angular extents for size and distance perceptions. Manipulations in the tunnel were expected to differentially affect perceived size (S') and perceived distance (D') as suggested by the paradox. While size contrast and depth cues were controlled for, effects of optical tunnel's structural relations on S' and D' were examined. Method 28 participants were divided into two groups across which the density of the optical tunnel was manipulated: dense versus sparse. For any of the two, one of four differently sized 2-D discs stuck on the center of a white sheet was placed in the middle of the tunnel at one of four locations. Participants viewed it monocularly, and reproduced its size and distance by adjusting a size meter and a distance meter respectively. Results Both S' and D' were underestimated in the tunnel but with different trends. D' was underestimated more at further locations for both groups, $F(3,78)=442.34$, $p< 0.001$. S', however, was underestimated less at further locations for the sparse group, $F(3,39)=3.32$, $p=0.030$; that is, S' increased with increasing underestimation of D'. Further, S' showed a quadratic trend for the dense group, $F(3,39)=12.30$, $p< 0.001$; specifically, S' increased and then decreased with increasing underestimation of D'. Discussion/Conclusion The effect of location on S' and D' showed a size-distance paradox for both dense and sparse optical tunnel conditions in slightly different ways. Given that size contrast and depth cues were controlled for in each tunnel condition, the paradoxical effect may be attributable to the optical tunnel's structural variable, possibly the ratio of the frontal surface area embedding the stimulus disc to the length and density of the visible longitudinal tunnel structure.

26.4037 A real-life size perception paradox

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The distance of an object from the observer and the size of its visual angle (projected size) are inversely correlated: as the distance of the object increases/decreases, its visual angle decreases/increases correspondingly. However, usually approximate size constancy prevails, that is, perceived sizes of objects are not strongly correlated with their distances. Here I report a curious case in which distance and perceived size of an object are directly correlated, that is, as the distance of the object increases/decreases, its perceived size tends to increase/decrease as well. The object in question is a church in Belgrade, Serbia, which can be observed from increasing distances first along a 400 meter street leading directly to it, then across a square at the other end of the street, and finally along an avenue for about 1000 meters. The phenomenon in question is that as one moves or drives along the avenue away from / towards the church, the church seems to grow larger/smaller. No formal experiment was performed but about a dozen people confirmed to the author the existence of the effect, once they were alerted to it. Photographs taken at various locations along the avenue and corresponding geometrical analyses revealed that as the observer distance from the church increases/decreases when moving along the avenue, its projected size increases/decreases relative to projected sizes of two hotel buildings located at the square, which flank the church as seen through the avenue corridor. Although separated by 400 meters in depth, when viewed from the avenue the church and the hotels are visually adjacent, and are perceived as being near each other in space. In such circumstances size judgments may be based on comparisons of visual angles of adjacent buildings. The phenomenon thus seems to be in accord with Gogel's equidistance principle and Rock's relative size principle.

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26.4038 Visual discovery of peripersonal space

Amitabha Mukerjee[1](amit@cse.iitk.ac.in), M. Ramaiah[1]; [1]Dept of Computer Science & Engg, Indian Institute of Technology, Kanpur

The ability to plan limb motions for everyday tasks is critical to survival, and a map for this space (the body schema), is encoded in terms of the various perceptual modalities along with motor data. However, the mechanisms for acquiring such a map and executing efficient limb motions on it are not well understood. In this work we present a computational model that suggests that starting from an ability to identify local perceptual or motor similarities, it is possible to construct non-linear maps (manifolds) for either the visual space, or the motor space. We show that these manifolds are homeomorphic (they can be mapped to each other), since they originate from the same low degree-of-freedom motion. This homeomorphism enables the creation of different fused manifolds with differing degrees of emphasis on each modality. Thus, a map focusing on images of the whole arm may be relevant to executing throwing actions, whereas a map for images of just the hand enables rectilinear motions for grasped objects, and a motor map would enable the discovery of muscle group synergies. We demonstrate how such a manifold may be constructed by combining evidence from thousands (potentially millions) of images across the motion space for each limb. Objects introduced into the reachable space are mapped in terms of image overlap with the pose memory, and reaching motions can be planned by traversing linear neighbourhoods (tangent spaces) on the non-linear manifold. Further, the visual body schema manifold may be particularly relevant when observing the motions of other agents with similar bodies. This motion space is also homeomorphic with the self-manifold, providing a possible visual mechanism for projecting these motions onto one's own body schema, enabling the gauging of motor intentionality in others.

26.4039 The Role of Parietal-Occipital Junction in the Interaction between Dorsal and Ventral Stream in Near and Far Space Processing

Aijun Wang[1,2,4](wangaijun41123@126.com), You Li[1], Ming Zhang[2], Qi Chen[1,3]; [1]Center for Studies of Psychological Application and School of Psychology, South China Normal University, Guangzhou, China, [2]Department of Psychology, Soochow University, Suzhou, China, [3]Epilepsy Center, Guangdong 999 Brain Hospital, Guangzhou, China, [4]School of Psychology, Northeast Normal University, Changchun, China

Neuropsychological and functional MRI data suggest that two functionally and anatomically dissociable streams of visual processing exist: a ventral perception-related stream and a dorsal action-related stream. However, relatively little is known about how the two streams interact in the intact brain during the production of adaptive behavior. Using functional MRI and a virtual three-dimensional paradigm, we aimed at examining whether the parietal-occipital junction (POJ) acts as an interface for the integration and processing of information between the dorsal and ventral streams in the near and far space processing. Our results showed that the POJ and bilateral superior occipital gyrus (SOG) showed relative increased activity when responded to targets presented in the near space than in the far space, which was independent of the retinotopic and perceived sizes of target. Furthermore, the POJ showed the enhanced functional connectivity with both the dorsal and ventral streams during the far space processing irrespective of target sizes, supporting the POJ acts as an interface between the dorsal and ventral streams in the near and far space processing. In contrast, the bilateral SOG showed the enhanced functional connectivity only with the ventral stream if retinotopic sizes of targets in the near and far spaces were matched, which suggested there was a functional dissociation between the POJ and bilateral SOG.

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26.4040 **Reconstructing 3D stimuli using BOLD activation patterns recovers hierarchical depth processing in human visual and parietal cortex** Margaret Henderson[1](mmhender@ucsd.edu), Chaipat Chunharas[1], Vy Vo[1], Thomas Sprague[1], John Serences[1]; [1]University of California, San Diego

The ability to recognize the location of objects in three-dimensional space is a key component of the human visual system, supporting complex behaviors such as navigation through the environment and the guidance of eye and limb movements. The distance of an object from an observer, or the object depth, is determined at least in part from binocular disparity information which is represented within several visual areas including V3A (Goncalves, 2015). However, the role of these areas in representing spatial locations in 3D space has not yet been determined. Here, we used analysis of BOLD fMRI activation patterns to determine how various retinotopically-defined visual areas represent information about the location of a stimulus in three-dimensional space. During imaging, participants viewed 3D spheres composed of multicolored flickering dots positioned at various locations in a horizontal plane, using binocular disparity goggles to generate an illusion of depth. Based on multivariate voxel activation patterns in areas V3A and IPS0, a linear classifier was able to categorize the depth position of a stimulus with above-chance accuracy, but activation patterns in V1 only reliably supported classification of the horizontal position. Furthermore, using an image reconstruction technique (inverted encoding model; see Sprague & Serences, 2013), we were successfully able to reconstruct an image of the stimulus viewed based on region-wide voxel activation patterns in V3A and IPS0. In contrast, early visual areas did not appear to represent information about the depth position of a stimulus but did carry information about horizontal position. These findings demonstrate that several visual areas contain representations of 3D spatial locations including depth, and may provide some insight into the hierarchy of spatial location encoding in the human visual system.

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Perceptual Organization: Grouping, contours and surfaces

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4041 **Reinterpreting Entropy: An edge-region grouping account of entropy effects on figure-ground organization** Joseph Brooks[1,2](J.L.Brooks@kent.ac.uk), Hilda Daníelsdóttir[2]; [1]Centre for Cognitive Neuroscience & Cognitive Systems, University of Kent, [2]School of Psychology, University of Kent

Figure-ground organization determines the shapes that we see at edges in images as is widely known by Rubin's faces-vase reversible image. Figure-ground assignment is influenced by a host of image-based cues as well as non-image factors such as attention. Recent work by Gillam and Grove (2011) has proposed a new cue of entropy which holds that regions containing high entropy (disorder) visual features are more likely to be perceived as background. This was tested in multi-partite images in which a rectangle was divided into columnar bars by straight edges and every other bar was filled with texture lines of several different random orientations (high entropy) or texture lines of all the same orientation (low entropy). The regions with high entropy lines were judged as in front less often than those with low entropy lines. We propose that these findings can be better explained as examples of the extant cue of edge-region grouping (Palmer & Brooks, 2008) rather than by a new entropy account. We conducted experiments to demonstrate this by varying the entropy of the texture lines within the regions but also independently varying the edge-region grouping relationship between the texture lines and the region borders. We found that edge-region grouping had a significant effect on perceived figure-ground organization whereas entropy did not. Our results suggest that edge-region grouping provides a better explanation of Gillam and Grove's findings than does the proposed entropy account.

Acknowledgement: ERASMUS Grant

26.4042 **Overweighting of outliers in the summary statistics of localization** James Moreland[1](jamesm37@uw.edu), Geoffrey Boynton[1]; [1]University of Washington

Observers have little difficulty when asked to localize the center-of-mass of an array of dots. However, it has been shown that subjects show small but systematic biases toward outlying dots in the array (McGowen et al. 1998). Here we replicated this bias toward outlying dots by having subjects estimate the center of mass of dots drawn from 2-D Gaussian distributions. We then predict our results using a standard model of V1 processing that explains how dots in less dense regions of an array have a relatively greater influence on the perceived center of mass. Subjects were presented with arrays of 10 dots drawn from a bivariate Gaussian distribution and were asked to estimate the center of mass with a mouse click. Eye movements were tracked during each trial, allowing us to measure both the end location of the first saccade and the reported estimate of the center of the array. We first estimated the relative influence of dots that fall within differing regions of local dot density by binning dots based on their density and applying linear regression to obtain weights for each density bin. An ideal observer should weigh each dot equally to determine the center of mass. However, we found that dots within regions of lower dot density had the greatest influence on the perceived center. Saccades were also more strongly influenced by dots located in less dense regions. We then developed a simple model that predicts perceived center of mass by convolving the stimulus image with a linear spatial filter, followed by a compressive nonlinearity. The center of mass of the resulting image is naturally pulled toward regions with lower dot density. Fits of this biologically plausible model to our data show that an exponent compressive nonlinearity explains our results well.

26.4043 **Perceptual size for local elements varies with the size of global arrangement** Taiichiro Uechi[1](taichiro.uechi@gmail.com), Makoto Ichikawa[2]; [1]Graduate School of Humanities and Social Sciences, Chiba University, [2]Faculty of Letters, Chiba University

In preliminary observations, we found that perceived size of elementary dots, which form a circular arrangement, decreases with the increment of the size of the global circular arrangement. We conducted an experiment to understand how the size of the global circular arrangement and actual size of the dots affect this size illusion. In the experiment, six black dots with an equivalent size (0.4, 0.6, or 0.8 arc degree) formed a circular arrangement on a white background. The diameter of the global circular arrangement was about 2.0, 2.5, 3.0, 3.5, 4.0, 4.5, 5.0, 5.5, or 6.0 arc degree. Participants observed those 27 stimuli with 57 cm viewing distance. Each of the 27 stimuli was presented four times in random orders. In each of the trial, a fixation point (+) was presented for 200ms on the center of the white display. Then, one of the 27 stimuli was presented for 1000ms at the center of the display. After each stimulus observation, a horizontal row of black dots with different sizes (0.64, 0.68, 0.72, 0.76, 0.8, 0.84, 0.88, 0.92, and 0.96 arc degree) was presented on the display. Participants selected one of the dots from the row whose size was perceptually equivalent to the size of the elementary dots in the stimulus. Our results showed that the perceived size for the elementary dots linearly increased with the decrement of the diameter of the global circular arrangement. In addition, this illusory effect for the size of elementary dots was exaggerated for the small element size in large circular arrangements. These results suggest that the perceived size of the local elements (dots) is affected by the contrast with the size of the global configuration (circular arrangement).

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26.4044 Reduced convexity context effects in elderly not attributable to reduced presumption of depth Jordan Lass[1](jwlass@gmail.com), Patrick Bennett[1], Mary Peterson[2], Allison Sekuler[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University, [2]Department of Psychology and Cognitive Science Program, University of Arizona

Convexity cues bias perceptual organization when observers resolve competing figure-ground (FG) interpretations of a stimulus. Convex regions are increasingly likely to be perceived as figures as the number of alternating, convex and homogeneously-filled concave regions in the surround increases (Peterson & Salvagio, 2008), and this Convexity Context Effect (CCE) is reduced in healthy aging (Lass, et al., 2012; 2013). The age-related CCE reduction has been interpreted as evidence for reduced suppression in seniors. However, CCEs may require inferring depth in the stimulus (Goldreich & Peterson, 2012), so reduced CCEs in aging may result from decreased depth presumption. If so, additional depth cues should increase the CCE in older adults. We tested this hypothesis in 24 younger (M=20.0, SD=1.7 years) and 24 older (M=71.8, SD=6.1 years) observers using a method that induces depth perception in younger adults (Froyen, et al., 2013): We filled alternating regions of 8-region displays with light or dark texture, and added horizontal motion that produced texture accretion/deletion at the bounding edges of the concave and/or convex regions. Stimuli were presented for 250 ms, and observers reported whether the light or dark region(s) appeared to be in the foreground. We predicted that the addition of opposing motion to both region types simultaneously would increase the CCE in older adults. In both age groups, moving regions were more likely to be perceived as background: relative to the baseline static condition, P(convex=figure) increased when motion was added to concave regions and decreased when added to convex regions. Critically, the addition of motion to both concave and convex regions simultaneously did not increase the CCE in either age group, despite this condition leading to an increased sense of depth. These results are inconsistent with the hypothesis that reduced CCEs in the elderly result from reduced presumption of depth in these stimuli.

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26.4045 Measuring the visual salience of smooth paths by their non-accidentalness Samy Blusseau[1], Alejandra Carboni[2], Alejandro Maiche[2], Jean-Michel Morel[1], Rafael Grompone von Gioi[1]; [1]CMLA, École Normale Supérieure de Cachan, Université Paris Saclay, France, [2]CIBPsi, Facultad de Psicología, Universidad de la República, Uruguay

A well known result in psychophysical studies of good continuation in arrays of Gabor patches is that the visual system is better at detecting smooth paths rather than jagged ones, and all the more so as they are formed by elements that are roughly aligned to the local tangent of the contour (association field, Field et al. 1993). Here we present a similar experiment on contour detection, and a stochastic model that predicts and interprets the perceptual thresholds for this task, relying on the non-accidentalness principle. Our experiment consists in an attentive contour detection task in arrays of Gabor patches. The visibility of contours among the cluttered background is affected by three varying parameters: the number of target elements, the amount of angular noise deviating their orientations from the local tangents to the contour, and the total number of patches in the image. Sixteen subjects took the experiment and their detection performance was compared to an artificial observer algorithm, on every stimulus. We built this algorithm on the a-contrario theory (Desoneux et al. 2008), applied here to formalize mathematically the non-accidentalness principle for good continuation and proximity. To predict the salience of curves, it associates with each candidate percept a measure, the Number of False Alarms (NFA), quantifying its degree of masking. The NFA showed a strong correlation with detection performance: different targets with the same NFA yielded similar levels of dectability among subjects. Furthermore, the algorithm's answers matched accurately those of human subjects, on average as well as on a trial-by-trial basis. The overall results give credit to the non-accidentalness principle, as a way to interpret and predict the perceptual grouping in masking conditions. Future work will concentrate on predicting the salience of symmetry using the same framework.

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26.4046 Measuring Selective Responses to Coherent Plaids Using the Intermodulation Term Darren Cunningham[1](lpxdc1@nottingham.ac.uk), Daniel Baker[2], Jonathan Peirce[1]; [1]University of Nottingham, [2]University of York

The visual system combines information that is propagated from the retina in order to generate a coherent percept of the environment. While much is known about how primary visual cortical mechanisms encode for low-level image features, relatively little is known about how this encoded information is then processed by mid-level mechanisms. By frequency tagging the components of a stimulus at different temporal frequencies and measuring steady-state visual evoked potentials (SSVEPs), we can examine the individual responses to each of the components at their fundamental component frequencies as well as various nonlinear interactions. Responses at the intermodulation frequencies (the sum and difference of the component frequencies) indicate nonlinearities at or after the point of combination. These can arise from either suppressive effects or combination effects such as AND responses to the compound. We have used the multi-component frequency-tagging technique to study responses to the combination of gratings into various plaid patterns. We combined two components (1cpd and 3cpd, respectively) into orthogonal plaid patterns with either matched spatial frequencies ('coherent' plaids) or non-matched ('non-coherent' plaids). Grating components were simultaneously flickered at different frequencies (2.3Hz, 3.75Hz) resulting in fundamental component-based responses at these frequencies, as well as intermodulation responses at their difference (1.45Hz) and sum (6.05Hz). The nonlinearities generated in response to the gratings and plaids were investigated by comparing several response frequencies. These included the component frequencies, the first-order intermodulation responses, and the various harmonic responses associated with these. The technique provides a rich set of data that we can investigate with a family of computational models. From this we can determine how the various nonlinearities (suppressive, additive etc.) contribute towards different response patterns. In particular, the harmonic of the sum intermodulation frequency appears in this case to differentiate second-order mechanisms from suppressive interactions in V1.

Acknowledgement: Engineering and Physical Sciences Research Council

26.4047 Gestalt grouping facilitates perceptual averaging to increase the efficiency of memory representations Jennifer Corbett[1](jennifer.e.corbett@gmail.com); [1]Bilkent University Department of Psychology/Neuroscience Program

The efficiency of averaging properties of sets of objects without encoding redundant details bears many similarities to previous Gestalt proposals that perception is parsimoniously organized as a function of recurrent order in the physical world, suggesting that grouping and averaging are part of a broader set of strategies the human visual system has developed to alleviate capacity limitations to represent visual information in the external environment. To examine how Gestalt grouping affects the manner in which information is averaged and remembered, I compared the error in observers' adjustments of remembered sizes of individual objects within and between sets defined by different Gestalt groupings. Observers viewed a study display of two sets of 8 heterogeneously-sized circles with different mean sizes, grouped by proximity, similarity, connectedness, or common region, followed by a test display of 6 homogeneously-sized test circles (3 per set) and adjusted the test sizes to match the remembered sizes of corresponding circles in the previous study display. As predicted, errors for items within the same Gestalt-defined group were more similar than errors between groups, such that individual circle sizes were recalled with bias towards respective set averages. Surprisingly, the duration of the study displays (500 ms or 5 seconds) had no significant effects on participants' errors. Furthermore, observers' error patterns could be classified by Gestalt grouping condition with significantly greater than chance (25%) accuracy. Taken together, results suggest that Gestalt grouping facilitates perceptual averaging to minimize the error with which individual items are encoded, optimizing the efficiency of VSTM. Overall, these findings support the proposal that the visual system relies on the canonical structure and statistical redundancy inherent in the surrounding environment to support our illusion of rich and stable perception, and raise intriguing possibilities for predicting how observers will encode and store sets of visual information.

26.4048 LabelMeSymmetry: a tool for human symmetry perception Chris Funk[1](funk@cse.psu.edu), Yanxi Liu[1]; [1]CSE and EE, College of Engineering, PSU

Even at a young age, most people can identify where symmetry resides within an image. However, there are no open datasets on human symmetry labels on real world images. There have been a few datasets created to compare symmetry detection algorithms but they have been limited and only labeled by a few individuals, preventing in depth study of symmetry perception on real images. We utilize an in-house crowdsourcing tool and the publicly available Microsoft COCO dataset to collect symmetry labels on real world images deployed on Amazon Mechanical Turk (AMT). The tool strives not to influence people's understanding of symmetry. For relatively low cost, the crowdsourcing tool has been able to create a dataset of 78,724 symmetry labels on over 1,000 images by 300+ AMTs from all over the world. To our knowledge, this is the largest dataset of symmetry labels for both perceived rotation symmetries and reflection (mirror) symmetries on natural photos. The labeled symmetries are then clustered automatically to find the statistical consensus on each image. Based on these consensuses, the Precision-Recall (PR) curves are analyzed between the different gender, education level and age group of the AMTs. No statistical difference is found between male and female AMTs, while statistically significant differences in symmetry perception are found between different education levels and age-groups. For example, we demonstrate p-value < 0.001 for AMTs of age 51-71 with all other age groups in PR performance, and doctoral/professional AMTs with all other education levels. The younger AMTs (less than or equal to 20 years old) and AMTs with high school education level, respectively, perform the best among all categories.

26.4049 **Do these lines look continuous?** William Harrison[1,2](willjharri@gmail.com), Katherine Storrs[3]; [1]Department of Psychology, University of Cambridge, [2]Queensland Brain Institute, The University of Queensland, [3]Medical Research Council, Cognition and Brain Sciences Unit

Spatially discontiguous sections of a partially occluded visual object are often easily identified as sharing a common source. For example, when two collinear lines abut opposite sides of a circle, we perceive a single line beneath a disc-shaped occluder. In the present study we investigated mechanisms involved in such amodal completion. Without an occluding surface, it is well established that observers are less sensitive to misalignments in oblique line segments than vertical line segments. We asked whether observers' vernier acuity for vertical and oblique lines predicts sensitivity to misalignments when the same lines are separated by an apparently occluding disc. We expected worse sensitivity when an occluder was present, due to additional visual noise in the positional mechanisms used to judge alignment, and that this noise might exacerbate the vernier oblique effect. Using a novel 2IFC method of constant stimuli that deconfounds sensitivity from biases such as the Poggendorff illusion, we compared observers' objective vernier acuity thresholds with and without an occluder. We found a large oblique effect, but, contrary to our predictions, no evidence that occluders affected observers' objective thresholds. We next measured observers' subjective thresholds when judging the apparent continuity of line segments under the same conditions and stimulus parameters. We reasoned that if observers' subjective judgments are informed by the same mechanisms used to detect misalignments, occluders should not influence appearance. However, observers reported that lines appeared continuous over a wider range of misalignments with an occluder than without, but only for oblique lines. This dissociation between objective and subjective thresholds suggests that the appearance of an occluded object involves mechanisms other than those used to detect the positions of the object parts.

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26.4050 **Extraction Dissonance: Not All Ensembles are Created Equal** Madison Elliott[1](maelliott1010@gmail.com), Ronald Rensink[2]; [1]Department of Psychology, University of British Columbia, [2]Department of Psychology, University of British Columbia

Our visual system is extremely proficient at extracting statistical information, such as the average size and density of objects. But what are the mechanisms supporting this? Here, we present a new methodology for exploring this issue, and use it to show that not all ensembles are treated alike by the visual system. To investigate the perceptual organization of ensemble structures, we began by examining the perception of Pearson correlation r in scatterplots. For plots with single data populations, discrimination performance is described simply: just noticeable differences (JNDs) are proportional to the distance from r=1. Our study expanded this to consider the case where each scatterplot not only contained a "target" population of black dots, but also an irrelevant "distractor" population of red dots (Fig. 1). Observers viewed two such scatterplots side-by-side (each containing both target and distractor populations), and were asked to identify the plot with the higher target correlation. There were 100 target dots in every condition. Interference from several distractor correlation values was determined by measuring JNDs for plots with various distractor dot numerosities: 100, 50, and 25 dots. Results showed a surprising effect: for target correlations of .3 with 100 and 50 distractor dots, discrimination declined considerably when the distractor correlation changed from .9 to .999. Meanwhile, for distractors of 25 dots, JNDs were low for both .9 and .999 distractor correlations (Fig. 2). This extraction dissonance, where discrimination is considerably different for ensembles with highly similar correlations, suggests that denser .999 populations may be represented similarly to a holistic unit, rather than an ensemble. More generally, our methodology provides exciting potential for exploring the level at which set of items can be perceived as a population, versus a single visual object.

Acknowledgement: Natural Sciences and Engineering Research Council, Canada. (NSERC)

Saturday PM

26.4051 **3-D amodal surface integration affected by real world knowledge of natural surfaces** Zijiang He[1], Teng-Leng Ooi[2], Yong Su[1]; [1]Department of Psychological and Brain Sciences, University of Louisville, [2]College of Optometry, The Ohio State University

The visual system represents partially occluded surfaces by filling in the missing/occluded surface segments in the back and integrating them with the visible surface segments. However, because the missing segments are not imaged on the retina, the underlying 3-D amodal surface integration process must rely on the visual system's internal knowledge of the real world. The challenge is to discover the nature of the knowledge. Here, we first revealed the amodal integration process uses knowledge that segments of a unitary surface have the same contrast polarity. Our experiment used a stereo display that rendered a horizontal rectangle been perceived as occluded by two vertical bars. Due to occlusion, the retinal images of the horizontal rectangle were broken into a middle segment sandwiched by the vertical bars and two outer segments. We found that segments with the same contrast polarity amodally integrated leading to the perceived depth of the middle segment with zero binocular disparity adopting the depth of the two outer segments with uncrossed disparity. But with opposite contrast polarity, the segments were perceived at different depths indicating a failure of amodal integration. Next, we manipulated the 3-D boundary contour alignment and 3-D surface curvature of the visible segments, and revealed that the amodal integration process also uses knowledge of natural surface being smooth. Finally, we investigated the influence of the occluding images (vertical bars). We found amodal integration became weaker with increasing widths of the occluding bars. Furthermore, whereas T-junctions formed between the vertical bars and the horizontal segments are critical for 2-D amodal integration, their significance reduces in favor of having a common binocular depth assignment for the visible segments in the 3-D display. Overall, our study reveals the visual system internalizes knowledge of real world surfaces and geometric relationships to represent partially occluded surfaces in 3-D space.

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26.4052 **Differentiating Local and Global Processes in Amodal Completion: Dot Localization with Familiar Logos** Susan Carrigan[1](susancarrigan@ucla.edu), Philip Kellman[1]; [1]University of California, Los Angeles

Previously, we reported evidence that competing global and local theories of amodal completion may reflect two different processes: a relatively local perceptual process that completes contours according to local geometry and produces precise boundary representations, and a more global recognition process that suggests likely shape based symmetry or familiarity but does not produce precise boundary representations. These two processes were distinguished experimentally via a dot localization procedure. Here, we applied the same method to test familiarity in amodal completion using familiar logos. Participants were assigned to either a local or a global condition, which determined how the participant was instructed to complete occluded logos. Global participants were instructed to complete the logo according to its familiar shape. Local participants were instructed to ignore the familiarity of the logo and instead complete the shape with a smooth contour according to the relatability of edges and endpoints. On each trial, an occluded logo was presented, and a small red dot was flashed on top of the occluder. Subjects made a forced choice of whether the dot fell inside or outside of the interpolated boundary. Interleaved adaptive 2-up, 1-down staircases were used to estimate two points on the psychometric function: the .707 probability that the dot was seen as outside of the occluded object's boundaries (outer threshold), and the .707 probability that the dot was seen as inside the occluded object's boundaries (inner threshold). We examined imprecision, measured as the distance between these two thresholds, location, measured as the mean of these two thresholds, and location error, measured as the absolute value of location. Consistent with earlier results regarding symmetry, the results reveal that, while local completion consistently produces precise and accurate boundary representations, global completion does not.

26.4053 **Is There a Common Mechanism for Path Integration and Illusory Contour Formation?** Philip Kellman[1](kellman@cognet.ucla.edu), Gennady Erlikhman[2], Susan Carrigan[1]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Psychology, University of Nevada, Reno

"Path integration" refers to the perceptual grouping of oriented elements embedded in a field of randomly arranged elements. Pop-out of a path of Gabor elements is not accompanied by the perception of illusory contours connecting the elements. The relation of path integration to contour interpolation, as in illusory and occluded contours, has remained unclear. Some theories (Grossberg & Mingolla, 1985; Kellman, Guttman & Wickens, 2001) posit an early, "promiscuous" contour-linking stage of processing, resulting in an intermediate representation; further constraints (e.g., presence or absence of homogeneous surface characteristics within and between elements) determine whether visible contours appear in final scene representations. We hypothesize that path detection reveals this intermediate representation that is shared with contour interpolation. Consistent with this idea, altering Gabor elements so that their centers match the background produces clear illusory contours connecting the elements in the path. We tested the connection between path integration and contour perception in a series of objective performance and subjective rating experiments, using standard Gabor elements and modified elements with centers matching the background that supported illusory contours along paths. Participants searched for targets composed of elements that were either perfectly aligned or misaligned by varying degrees in a standard 2IFC path detection paradigm. The results reveal a clear correspondence between the two kinds of displays: path detection performance decreased as a function of degree of misalignment, and was indistinguishable for the two path types. Both sets of results confirmed earlier findings that illusory and occluded contour interpolation break down at about 15-20 arc min of retinal misalignment (Kellman & Shipley, 1991). Subjective ratings of perceived illusory contours as a function of misalignment, for the modified element displays, mirrored the path detection results. These results suggest that path integration reflects the earlier stage of a common contour-linking and contour interpolation mechanism.

26.4054 **Contour constraints on the perception of surfaces and occlusions** Juno Kim[1](juno.kim@unsw.edu.au), Stuart Anstis[2]; [1]University of New South Wales, Sydney, Australia, [2]University of California San Diego

Contours can be generated by any one of several possible physical events, including texture, occlusion and specular reflectance. Previous research has shown the classification of contours as texture depends on the pattern of shading adjacent to contour boundaries (e.g., Marlow, Kim & Anderson, 2011). These textural boundaries preserve shading gradients across edges generated by local changes in albedo (Ben-Shahar & Zucker, 2001). Unlike textures, occlusion boundaries have very different constraints that cause shading discontinuities (Ben-Shahar, Huggins & Zucker, 2002), including extremal shading toward the contour that is informative for making figure-ground distinctions (Palmer & Ghose, 2008). It is possible that the differentiation of occlusion boundaries from textural boundaries might depend generically on variation in shading direction across contours. We undertook a series of experiments to systematically vary the shading across reflectance boundaries generated by the surfaces of 3D rendered objects. We initially painted our surface with a dark and light texture similar to military camouflage. The lighting direction was parametrically varied to generate changes in shading across reflectance boundaries. For example, we rendered the lighter regions with a light source directed from above (at 0 degrees) and the darker regions with a light source directed from different orientations ranging up to 180 degrees. We refer to this change in the direction of local gradients as the delta shading angle. Increasing the size of delta shading caused the edge to no longer appear as a reflectance boundary, but instead, appear as an occlusion boundary. We find that the side of the contour perceived as figure or ground depends on a light-source from above prior. The resulting apparent break in surface continuity is also sufficient to support amodal completion. We conclude that the classification of contours, and the interpretation of gradients that define them, depends on more than just low-level visual processing.

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26.4055 **Average size estimation of dots completing behind an illusory surface is precise** Swati Pandita[1](swati.panda93@gmail.com), Sneha Suresh[1], Jason Haberman[1]; [1]Rhodes College

The environment is replete with redundant visual information, which the visual system can compress into an efficient, ensemble representation. Ensemble perceptual systems have been shown to operate with remarkable flexibility across a host of visual domains. In the current set of experiments, we however, tested whether ensemble information may be represented at a conceptual level, that is, derived in the absence of physical stimuli. In an extension to Emmanouil and Ro's work on conceptual size averaging (VSS, 2015), we used illusory surfaces, Kanizsa triangles, to partially occlude sets of discs varying in size, instead of solid, visible bars. Our results revealed that observers could represent the average size of discs that were partially occluded by an illusory surface just as well as when the discs were fully visible. In a series of follow-up experiments, we tested whether observers implicitly represented the amodally completed surface. Observers judged which of two successively presented pacman sets, one of which gave rise to illusory contours (Kanisza configuration) and one of which did not, had the larger average size. To our surprise, there was no bias to perceive the average size of the Kanizsa configuration as larger, even though the pacman amodally completed behind the illusory surface. It seems that observers were unable to remove the missing 'pie wedge' in their estimation of mean size in either pacman configuration.

26.4056 **Dissociating the effects of contour smoothness and task-specific bias on the association field mechanism of contour integration** Zhiheng Zhou[1](zhzhou44@gmail.com), Lars Strother[1]; [1]University of Nevada, Reno

Contour integration relies on neural mechanisms sensitive to contour smoothness, such as the association field (AF) proposed by Field et al. (1993). We conducted three experiments to test whether or not the sensitivity of the AF to contour smoothness elicits similar effects for a contour detection (CD) experiment and two novel contour camouflage experiments (CC1 and CC2). In the CD task, background elements were successively removed until a target contour became visible. In the CC1 task, a contour appeared against a static background of constant density and remained visible for up to a few seconds and then became camouflaged. In the CC2 task, a contour became camouflaged as the density of a dynamic background was increased. In all three experiments we observed sensitivity to parametric manipulation of contour smoothness. Importantly, individual observers' sensitivities to contour smoothness were strongly correlated across all three experiments, which suggest the involvement of a common AF mechanism. In addition to correlating smoothness sensitivity, we examined prospective correlations for task-specific bias (i.e. willingness to report that a contour had become visible or disappeared) across the experiments. Interestingly, we found that this bias only correlated between the CC1 and CC2 experiments in which contours became camouflaged. Taken together, our findings suggest that AF sensitivity to image-based influences (contour smoothness) is not task-specific, and it can be dissociated from top-down effects on the AF hysteresis related to task-specific bias.

26.4057 **Does Event Perception Depend on IQ, Expertise, and Repetition?** Tandra Ghose[1](tandra@berkeley.edu), Katharina Sebastian[1], Markus Huff[2]; [1]Department of Psychology, University of Kaiserslautern, Germany, [2]Department of Cognitive Psychology, University of Tübingen, Germany

Event Segmentation Theory (EST) explains the perceptual organization of an ongoing activity into meaningful events. Classical event segmentation task involves watching an online video and indicating with keypress, the event boundaries i.e., when one event ends and the next one begins. The resulting hierarchical organization of object-based coarse-events and action-based fine-events provide insight about various cognitive processes. We studied event perception in the domain of assistance and training systems development for assembly workers in industrial settings. We investigated event segmentation performance of 32 intellectually-disabled people (mean IQ = 64.4) compared to 30 controls (IQ>100). Stimuli: One "breakfast-making" video and three assembly task videos. 38% Intellectually-disabled participants defined more coarse-events than fine-events, indicating misconception of higher- and lower-level content. The remain-

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ing 62% showed diminished hierarchical alignment compared to controls. We suggest that simple event segmentation task can serve as diagnostic assessment for intellectually disabled workers' cognitive potential. Furthermore, we investigated how repeated practice of sequential assembly tasks in virtual training influences learning of the task's coarse and fine assembly steps in car door assembly for domain experts (N = 18) and novices (N = 19). Stimuli: A video of car door assembly task. The video stopped at time points associated with the coarse-event boundaries; either before a coarse-event boundary – this tested memory for coarse-events - or after a coarse-event boundary – this tested memory for fine-events. We found virtual training enhances ability to predict object-based coarse-event from nearest fine-event boundary. It did not improve memory for action-based fine-event from the nearest coarse-event boundary. Expertise had a positive effect on memory for fine assembly steps. Our research in event perception can help improve the quality of life of workers at various levels- experts, new hires, and intellectually-disabled workers, by identifying gaps in existing assistance systems for the different user groups.

Scene Perception: Categorization and memory

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4058 Co-registration of eye movements and EEG to study semantic congruency during scene perception

Hélène Devillez [1](Helene.Devillez@Colorado.EDU), Randall O'Reilly[1], Tim Curran[1]; [1]Department of Psychology and Neuroscience, University of Colorado Boulder

Visual selection processes in real-world scenes are guided by exogenous and endogenous factors. Endogenous factors correspond to top-down influences like the cognitive tasks or prior knowledge. Object processing is affected by the gist of the scene within which it is embedded and the prior knowledge about the objects. On one hand, it has been shown that incongruent objects result in prolonged and more frequent eye-fixations than congruent objects (Underwood et al, 2008; Võ & Henderson, 2009). On the other hand, previous event-related potential (ERP) research has suggested that manipulating the semantic congruency between an object and the surrounding scene affects the high level representation of that object (Ganis & Kutas, 2003). The congruency effect is reflected by a late ERP resembling the N300/N400 effect previously associated with semantic integration (Mudrik, Lamy, & Deouell, 2010). The present study investigates the effect of semantic congruency on scene processing using eye-fixation related potentials (EFRPs). We simultaneously registered electroencephalographic (EEG) and eye-tracking signals of participants exploring natural scenes during 4 sec in preparation for a recognition memory test. We compared EFRPs evoked by congruent vs. incongruent eye-fixations (e.g., a fork in a kitchen vs. the same fork in a bathroom). First, we replicated previous eye movement results, showing that incongruent objects were more fixated and for a longer duration than congruent objects. Second, the EFRP analysis revealed that both early and late EFRPs were influenced by the congruency effect. The P1 EFRP and a late EFRP emerging around 260 ms after the fixation onset were modulated by semantic congruency. The top-down encoding of the scene was built during the first eye fixations; a mismatch between the semantic knowledge of objects and the features of the scene affected the scene exploration. These results suggest that top-down information influences early object processing during natural viewing.

Acknowledgement: Office of Naval Research (ONR) N00014-14-1-0670

26.4059 The 'Gist' of the Abnormal in Radiology Scenes: Where is the Signal?

Karla Evans[1](karla.evans@york.ac.uk), Julie Cooper[2], Tamara Haygood[3], Jeremy Wolfe[4]; [1]Department of Psychology, University of York, [2]Department of Radiology, York Teaching Hospital, [3]Department of Diagnostic Radiology, UT M.D. Anderson Cancer Center, [4]Visual Attention Lab, Harvard Medical School, Brigham and Women's Hospital

Humans are very adept at extracting the "gist" of a scene in as little as a fraction of a second. This "gist" perception can be learned for novel stimuli. We have found that this extends to the gist of breast cancer. Radiologists can distinguish between normal mammograms and those containing subtle signs of cancer at above chance levels with 250 msec exposure but are at chance in localizing the abnoramility. This pattern of results suggests that they are detecting a global signal of abnormality. What are the stimulus properties that might support this ability? Across four experiments, we systematically investigated the nature of the "gist" signal by asking radiologists to make detection and localization responses about briefly presented mammograms in which the spatial frequency, symmetry and/or size of the images was manipulated. Interestingly, the signal is stronger in the higher spatial frequencies. Performance is poor with low-pass filtered images but almost as good with high-pass as with unfiltered images. Performance does not depend on detection of breaks in the normal symmetry of left and right breasts. Moreover, above chance classification is possible using images of the normal breast of a patient with overt signs of cancer in the other breast. Some signal is present in the portions of the parenchyma (breast tissue) that do not contain a lesion or that are in the contralateral breast. This signal does not appear to be a simple assessment of breast density. The experiments indicate that detection may be based on a widely-distributed image statistic, learned by experts (Non-expert observers perform at chance). The finding that global signal related to disease can be detected in parenchyma independent of the appearance of the cancer may have further relevance in the clinic.

26.4060 Classification images of multispectral and fused natural scenes

Jennifer Bittner[1](Jennifer.L.Bittner@gmail.com); [1]NRC Resident Research Associate at the Air Force Research Laboratory, 711HPW/RHCV

Image fusion is a specific type of image manipulation that aims to enhance human visual perception and performance. Through the combination of images captured in varying spectral bands (e.g. visible, thermal, night vision), image fusion attempts to provide a "best of both worlds" presentation within a single output image. Past studies using ideal observer analysis to examine the impact of image fusion upon visual perception (i.e., Bittner, et al. VSS 2014) have found that, contrary to fusion goals, simple Landolt C images captured in single spectral bands can affect human efficiency as much or more than their corresponding fused images. The current work expands this examination in technique and stimulus complexity, using response classification to consider the proportion of information (i.e. stimulus features) utilized by humans in natural scenes as they are manipulated between single-band imagery and image fusion presentations. Classification image results reveal that, in a simple 1-of-2 choice task of an actor holding a shovel on opposing sides of his body, different areas of the stimulus are utilized by humans dependent on the type of imagery presented. Specifically, the areas used in the fused images parallel those used in the component thermal imagery but not in the component visible imagery. Initial results of a second study indicate that these patterns augment when given a change to task and stimulus content. This work applying response classification to image fusion provides not only an examination of the stimulus components used by the visual system in scenes, but also bridges the worlds of applied and vision science research, expanding the general framework for analyzing the influence of image enhancement in direct relation to the human visual system.

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26.4061 Visual statistical learning at basic and subordinate category levels in real-world images

Jihyang Jun[1,2](jihy.jun@gmail.com), Sang Chul Chong[1,2,3]; [1]Center for Cognitive Science, Yonsei University, [2]Graduate Program in Cognitive Science, Yonsei University, [3]Department of Psychology, Yonsei University

Previous studies on visual statistical learning (VSL) showed that when statistical regularities were constructed by real-world images with semantic information, participants could extract statistical regularities at a basic category level (Brady & Oliva, 2008) as well as at its subordinate object level (Otsuka, Nishiyama, Nakahara, & Kawaguchi, 2013). However, how the statistical regularities at the basic and subordinate levels interacted with one another has not been investigated. The current study examined whether statistical regularities at a basic category level influenced the extent of VSL at a subordinate object level. In a familiarization phase, participants detected a repetition of the same image as a cover task, while different real-world object images appeared sequentially. Within this temporal stream, statistical regularities at a subordinate object level existed among three different images, which constructed sets of triplets and always appeared in the same order (e.g., a parrot, a sports car, and then a gold fish). For half sets of triplets, temporal regularities also existed at a basic category level (e.g., categories of bird, car, and fish in a fixed order), whereas the other half of triplets did not include such basic-level regularities (e.g., categories of dog, flower, and house in a variable order). A total 6 sets of triplets were used. These are more than 4 sets of triplets typically used in the previous studies. In a test phase, participants were instructed to judge whether each triplet was familiar or not (two-alternative forced-choice) while learned and unlearned triplets were pre-

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sented. Results showed that participants extracted statistical regularities across the six triplets. However, the extent of learning was not different between triplets with and without regularities at a basic category level.

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26.4062 **Effect of Viewpoint Change in Implicit Learning of a Scene: Evidence from Contextual Cueing Paradigm**

Shiyi Li[1, 2](elevenny@hotmail.com), Chao Wang[1, 2], Xuejun Bai[1], Hong-Jin Sun[2]; [1]Academy of Psychology and Behavior, Tianjin Normal University, [2]Department of Psychology, Neuroscience & Behaviour, McMaster University

Repeated configurations of random elements induce a better search performance than that of the novel random configurations (contextual cueing effect, Chun and Jiang, 1998). We examined the effect of viewpoint change of a scene in a contextual cueing paradigm using a computer rendered illustration of a realistic scene. The scene contained an array of chairs of different shapes which were randomly positioned on the ground but oriented coherently. Observers were required to search for and identified an arbitrarily located target letter positioned on the surface of the seat of a chair. Half of the scenes were repeated over blocks and the other half were not. A typical contextual cueing effect (faster search for the repeated scenes than the novel scenes) were found. Following learning, participants continued to perform the search task (testing phase), but orientation of the entire scene (Experiment 1) or individual chairs (Experiment 2) was either changed (experimental group) or not (control group). For the experimental group, in Experiment 1, the viewpoint of the scene was rotated 45°. Moreover, a video illustrating such change for one typical scene was presented to the participants before the testing phase. In Experiment 2, the experimental group viewed the same video as in Experiment 1, but during the testing phase the viewpoint of the scene did not change, instead, each chair rotated in place 45° in the ground plane, creating a false sense of viewpoint change (or scene rotation). In the testing phase, contextual cueing effect was still evident (although with some reduction) in Experiment 1 but not in Experiment 2. These results suggest that implicit learning can be transferred to a new viewpoint and such transfer could be achieved through mental update of the view. Such update appears to be automatic and prompted by proper cues about rotation.

Acknowledgement: NSERC

26.4063 **Does Scene Perception Involve an Active Schema?**

Trang Nguyen[1](trang@mail.usf.edu), John Defant[1], Steven Schultz[1], Thomas Sanocki[1]; [1]Psychology, University of South Florida

Results indicating rapid integration of the multiple types of information in a scene have led a number of investigators to propose that scene perception involves a schema (e.g., Fei-Fei, Greene, Intraub, Palmer). What is a schema, and what is an active schema? A schema can be viewed as a network for accepting information about scenes, with nodes representing important entities (e.g., object, surfaces, functions). Previous results indicated that the network can be primed by presenting scenes with similar entities (scenes with active people, or with building structures), resulting in more rapid subsequent perception of prime-consistent details (Sanocki & Schultz, VSS 2015). Here we ask how active this network is: Can it speed the perception of entities that are abstractly related to the primes? For example, when primed for building structures, will observers more rapidly encode information about art structures that are not buildings? Can scenes depicting different groups of animals prime an abstract identity schema that rapidly encodes people? Observers viewed a series of pictures and wrote brief descriptions of what they saw after each picture. After 5 prime pictures, the scenes on critical trials 6 and 7 contained both art structures and people (150 ms durations). Results indicate that the scene schema is moderately abstract but not highly abstract. Building structures primed art structures, and a mixture of animals and adults primed children. But a mixture of animals did not prime children. The pattern of results was observed for first mention (of people or structure), consistent with the idea that a schema serves to prioritize scene information. A similar pattern was observed for total correct words. An additional finding was that the full reports were quite accurate overall; perception was determined by scene content, not by general expectations.

26.4064 **Exploring scene categorization based on the orientation distribution of natural images**

April Schweinhart[1](schweinharta@gmail.com), Baxter Eaves[1], Patrick Shafto[1]; [1]Mathematics and Computer Science, Rutgers University-Newark

The visual environment has a predictable anisotropic distribution of content which the human visual system appears to take advantage of after sufficient experience (Hansen & Essock, JoV, 2004; Schweinhart & Essock, Perception, 2013). While the general pattern of anisotropy has been found to be a good match to perceptual biases (Haun, Kim, & Essock, JoV, 2009), there is substantial variation both between and within the distributions for different environments (e.g. Girshick, Landy, & Simoncelli, Nat. Neuro., 2011) which can be modeled via a mixture distribution (Eaves, Schweinhart, & Shafto, in press). Here we explored methods for automatically summarizing and "teaching" people about the clusters of variation within indoor and outdoor scenes based on their orientation distribution. A sample of images was taken from videos recorded as observers walked around different types of environments (a nature preserve, a house, a city, a University, etc) and the amplitude of characteristic orientations was extracted (0,45,90,135). We then compared observers' ability to categorize sample images based on pairs of exemplars which 1. best summarized the category means, 2. summarized the sufficient statistics of the distributions, or 3. were chosen to optimally teach (Shafto & Goodman, Proc. Cog. Sci., 2008; Eaves, Schweinhart, & Shafto, in press). When the categories were not well separated and therefore difficult to distinguish, observers were more accurate when they were given exemplars chosen by the more complex methods than when the exemplars simply matched the mean of the orientation distribution. This work suggests that the orientation distribution of images can capture meaningful information about the conceptual category of the scene. Furthermore, the perceptual results have potential implications for fields in which visual training and image categorization are important.

26.4065 **Panoramic Memory Shapes Visual Representations of Scenes**

Caroline Robertson[1,2](carolinerobertson@fas.harvard.edu), Katherine Hermann[2], Anna Mynick[3], Dwight Kravitz[4], Nancy Kanwisher[2]; [1]Harvard Society of Fellows, Harvard, Cambridge, MA, [2]McGovern Institute for Brain Research, MIT, Cambridge, MA, [3]Wellesley College, Wellesley, MA, [4]George Washington University, Washington, DC

As we navigate around our visual environment, our awareness of the place we are in seems to extend beyond the specific part of the environment that is currently in view to include a broader representation of the scene all around us. Here, we tested whether memory of a broad, panoramic space influences the ongoing representations of discrete views from within that panorama. Specifically, we introduced participants (N=21 behavioral study; N=12 fMRI study) to dynamic fragments of novel 360° spatial expanses, some of which contained overlapping visual content (Overlap Condition), and others of which did not (No-Overlap Condition) (Study Phase). Then, we tested whether discrete, non-overlapping snapshots from opposite edges of these spatial expanses become associated in memory, and acquire representational similarity in the brain, as a function of whether the visual information connecting them is known or unknown (Overlap vs. No-Overlap). On each trial of the fMRI study, participants were presented with single snapshots from the studied spatial expanses. Classification analyses showed that all independently-localized regions of the scene network (PPA, RSC, OPA) were able to discriminate individual scenes (all $p< 0.001$) and spatial layout (open/closed) (all $p< 0.05$). Importantly, representations in one region of the scene network were also sensitivity to broader spatial knowledge: the RSC showed significantly greater representational similarity between pairs of snapshots that had appeared in the Overlap vs. the No-Overlap condition ($p< 0.008$). Behaviorally, memory for the association between two snapshots was higher if they were were drawn from the Overlap vs. No-Overlap conditions (all $p< 0.02$), as was spatiotopic position memory ($p< 0.02$). Our results demonstrate that images of visual scenes evoke greater representational similarity in the brain when the visual information that unites them has been previously observed, suggesting that moment-to-moment visual representations are shaped by broader visuospatial representations in memory.

26.4066 **Effects of prior tasks on priming for distance judgments in scenes**

Carmela Gottesman[1](cvgottesman@sc.edu); [1]University of South Carolina Salkehatchie

Prior research has shown that distance judgments in pictures of natural scenes are faster when the scenes are primed with a picture that shows the layout of the scene as opposed to a different prime. This study looked at the effect of different kinds of prior processing of the same pictures on this priming effect. First viewers saw 120 pictures of scenes, and had to make one of two judgments; they were either asked to judge if there were people in the scene and if so were there a few or many, or they were asked to judge the direction of the picture's layout (is the layout drawing the eye to the right, to the left, or straight forward) . In the second block, they saw the same pictures again primed either by the same scene or by a neutral stimulus that showed no scene layout (following Sanocki & Epstein, 1997). Two dots were added to the pictures and people had to judge which dot was close to them (or to the camera when the picture

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was taken). Priming calculated as the difference in RT when the judged picture followed an abstract prime compared to when it followed a prime showing the same scene (without the to-be-judged dots). The priming in the second block was significantly affected by the type of processing that people engaged in the first part of the study. Viewers who engaged in the non-spatial task, judging the number of people in the scene, were helped more by the scene primes in the second block (showed more priming), than viewers who engaged in the spatial task. The results indicate that simply seeing the layout of the scene previously does not assist spatial judgments as much as seeing the picture while paying attention to the layout.

26.4067 **More than meets the eye: Raw scanpath replay is an insufficient memory cue for static and dynamic scenes.** Tim Smith[1](tj.smith@bbk.ac.uk), Sofia Ciccarone[1]; [1]Psychological Sciences, Birkbeck, University of London

Memory for dynamic scenes is better than static versions (Matthews et al., PB&R, 2007) and this may be due to increased gaze guidance by visual salience (Smith & Mital, JoV, 2013) increasing the chance of reinstating the same scanpath during recognition and encoding. Replaying only the fixated parts of a static scene during recognition (via a moving window) has been shown to improve memory performance compared to different locations (Foulsham & Kingstone, JEP:G, 2013). However, it is not known whether this effect is enhanced in more naturalistic dynamic scenes. Across two experiments, old/new recognition memory for dynamic and static scenes was tested under three conditions: 1) Full scene; 2) Own, a 6.2° moving-window yoked to the participant's raw gaze location from encoding; or 3) Other, a moving-window with the scanpath from a different scene. In experiment 1, memory was tested for 192 three second clips either immediately after study, or after a delay of one or two weeks. Analysis of accuracy and d' showed a significant decrease in performance with delay (immediate>one week = two week) and significantly better memory for Full compared to Own and Other moving windows. However, Own was significantly better than Other, confirming the fixation-dependent recognition effect and extending it to dynamic scenes. Surprisingly there were no differences between static and dynamic scenes. This was confirmed in a second experiment using immediate recall and a blocked design with the Full condition before either moving window condition. These results indicate that scene memory privileges fixated locations but that peripheral details are also important. Whether it is the fixated scene content or the scanpath that is important for cuing memory is not currently known. Future studies must attempt to dissociate these factors and also investigate the conditions under which memory for dynamic scenes is superior to static scenes.

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Scene Perception: Gaze, models, and mechanisms

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4068 **A Neural Algorithm of Artistic Style** Leon Gatys[1,2,3](leon.gatys@bethgelab.org), Alexander Ecker[1,2,4,5], Matthias Bethge[1,2,4]; [1]Werner Reichardt Centre for Integrative Neuroscience and Institute of Theoretical Physics, University of Tübingen, Germany, [2]Bernstein Center for Computational Neuroscience, Tübingen, Germany, [3]Graduate School for Neural Information Processing, Tübingen, Germany, [4]Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [5]Department of Neuroscience, Baylor College of Medicine, Houston, TX, USA

In fine art, especially painting, humans have mastered the skill to create unique visual experiences by composing a complex interplay between the content and style of an image. The algorithmic basis of this process is unknown and there exists no artificial system with similar capabilities. Recently, a class of biologically inspired vision models called Deep Neural Networks have demonstrated near-human performance in complex visual tasks such as object and face recognition. Here we introduce an artificial system based on a Deep Neural Network that creates artistic images of high perceptual quality. The system can separate and recombine the content and style of arbitrary images, providing a neural algorithm for the creation of artistic images. In light of recent studies using fMRI and electrophysiology that have shown striking similarities between performance-optimised artificial neural networks and biological vision, our work offers a path towards an algorithmic understanding of how humans create and perceive artistic imagery. The algorithm introduces a novel class of stimuli that could be used to test specific computational hypotheses about the perceptual processing of artistic style.

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26.4069 **Ensemble perception involves more than means and standard deviations: Mapping internal probabilities density functions with priming of pop-out** Andrey Chetverikov[1,2,3](andrey@hi.is), Gianluca Campana[4,5], Árni Kristjánsson[1,6]; [1]Faculty of Psychology, School of Health Sciences, University of Iceland, [2]Cognitive Research Lab, Russian Academy of National Economy and Public Administration, [3]Department of Psychology, Saint Petersburg State University, [4]Department of General Psychology, University of Padova, [5]Human Inspired Technology Research Centre, University of Padova, [6]Institute of Cognitive Neuroscience, University College London

Observers can estimate summary statistics of visual ensembles, such as the mean or variance of distributions of color, orientation or motion. But attempts to show that the shape of feature distributions is accessible have not been successful. Using a novel "priming of pop-out" paradigm we show for the first time that observers encode not only means and standard deviations of orientation distributions, but also their shape. Observers searched for an oddly oriented line in a set of 36 lines. Within streaks of 5 to 7 trials, distractor orientations were randomly drawn from a pre-defined distribution while target orientation differed by 60 to 120 degrees from the distractor distribution mean. We analyzed RTs on the first trial of each streak by orientation difference between the present target and the mean of preceding distractor distribution (T-PD distance). We replicate effects of distractor heterogeneity and observers' sensitivity to the mean and variance of preceding distributions. Most importantly, however, we demonstrate that repetition effects differ following uniform and normal distributions of identical range. We assume that the higher the subjective probability (learned in a previous streak) that a stimulus with a given orientation is a distractor, the longer the RTs when it is a target. Following a normal distribution, RTs gradually decrease as T-PD increases. Following a uniform distribution, responses are similarly slow when the target falls within or close to the range of a preceding distractor distribution, but only when T-PD further increases do RTs decrease. Distribution shape is, in other words, reflected in the RTs: RTs and hence the corresponding expectations are "uniform" when the preceding distractor distribution is uniform. We conclude that observers are able to encode the shape of stimulus distributions over time and that our novel paradigm allows the mapping of observers' internal probability density functions with surprising precision

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26.4070 **How temporal context predicts eye gaze for dynamic stimuli** Cameron Ellis[1](cellis@princeton.edu), Patrick Harding[2], Judith Fan[1], Nicholas Turk-Browne[1,3]; [1]Department of Psychology, Princeton University, [2]Goethe-Universität Frankfurt, [3]Princeton Neuroscience Department

What determines where we look during natural visual experience? Computer vision algorithms successfully account for gaze behavior in static scenes, but may be insufficient for modeling visual selection in dynamic scenes. This will likely require consideration of how image features evolve over time. For instance, where we attend might be constrained by where we have attended previously, by how long an object has been visible, and by expectations about when and where something will appear. To start bridging this gap, we adapted an algorithm originally developed to extract regions of high visual interest from static images (Harding & Robertson, 2013, Cogn Comput) to additionally capture how temporal information guides visual selection in dynamic scenes. Eye gaze was monitored in a group of 24 observers while they watched a series of short video clips depicting real-world indoor and outdoor scenes (Li et al., 2011, IMAVS). To ensure engagement, observers were occasionally prompted to describe what happened in the previous clip. Static visual-interest maps, generated by applying the original algorithm to each video frame independently, reliably predicted the distribution of eye fixations. However, we were able to influence model performance by adjusting two new parameters that incorporated information about temporal context when creating visual-interest maps: 'history', which placed additional weight on regions with high visual interest in preceding frames; and 'prediction', which

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placed additional weight on regions with high visual interest in subsequent frames. Further analyses examine whether the history and prediction of actual eye fixations provide additional explanatory power, how long of a temporal window in the past and future is most informative, and how different time samples should be weighted. The ultimate goal is to develop a refined model that better accounts for natural visual behavior and to understand how temporal context biases the allocation of attention.

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26.4071 Eye movement patterns during scene viewing predict individual differences Taylor Hayes[1](trhayes@ucdavis.edu), John Henderson[1]; [1]Center for Mind and Brain, University of California, Davis

An important and understudied area in scene perception is the degree to which individual differences influence scene-viewing behavior. The present study investigated this issue by predicting individual differences from regularities in sequential eye movement patterns. Seventy-nine participants completed a free-view memorization task for 40 real-world scenes while their eye movements were recorded. Individual difference measures were collected across subsets of participants including cognitive ability measures (e.g., working memory capacity) and cognitive disorder measures (e.g., autism spectrum disorder: ASD). An area of interest grid composed of 5 radiating rectangular areas from the scene center to the periphery was used to represent observers' tendencies to shift their attention between more central or peripheral scene information. Successor Representation Scanpath Analysis (SRSA, Hayes, Petrov, & Sederberg, 2011) was used to capture statistical regularities in each participant's eye movements across this predefined area of interest grid. A principal component analysis of participant successor representations was performed for each individual difference measure, and these components were then used to predict individual differences scores. SRSA was able to predict several individual difference measures well. Leave-one-out cross validation demonstrated significant prediction across the following measures: working memory capacity ($r2=0.45$), fluid intelligence ($r2=0.43$), SAT ($r2=0.45$), and ASD ($r2=0.26$). Moreover, the component regression weights were readily interpretable in terms of broad scanning strategies. For instance, higher cognitive ability was associated with the tendency to focus attention more centrally within a scene, and move more systematically among these central areas. Participants with higher ASD scores showed a different pattern, with a greater tendency to focus attention more peripherally within a scene, and move less systematically between the center and periphery of the scene. These results suggest that underlying individual differences in observers significantly influence gaze behavior during real-world scene perception.

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26.4072 DeepGaze II: A big step towards explaining all information in image-based saliency Matthias Kümmerer[1](matthias.kuemmerer@bethgelab.org), Matthias Bethge[1,2,3]; [1]Werner-Reichardt-Centre for Integrative Neuroscience, University Tübingen, [2]Bernstein Center for Computational Neuroscience, Tübingen, [3]Max-Planck Institute for Biological Cybernetics, Tübingen

When free-viewing scenes, the first few fixations of human observers are driven in part by bottom-up attention. Over the last decade various models have been proposed to explain these fixations. We recently standardized model comparison using an information-theoretic framework and were able to show that these models captured not more than 1/3 of the explainable mutual information between image content and the fixation locations, which might be partially due to the limited data available (Kuemmerer et al, PNAS, in press). Subsequently, we have shown that this limitation can be tackled effectively by using a transfer learning strategy. Our model "DeepGaze I" uses a neural network (AlexNet) that was originally trained for object detection on the ImageNet dataset. It achieved a large improvement over the previous state of the art, explaining 56% of the explainable information (Kuemmerer et al, ICLR 2015). A new generation of object recognition models have since been developed, substantially outperforming AlexNet. The success of "DeepGaze I" and similar models suggests that features that yield good object detection performance can be exploited for better saliency prediction, and that object detection and fixation prediction performances are correlated. Here we test this hypothesis. Our new model "DeepGaze II" uses the VGG network to convert an image into a high dimensional representation, which is then fed through a second, smaller network to yield a density prediction. The second network is pre-trained using maximum-likelihood on the SALICON dataset and fine-tuned on the MIT1003 dataset. Remarkably, DeepGaze II explains 88% of the explainable information on held out data, and has since achieved top performance on the MIT Saliency Benchmark. The problem of predicting where people look under free-viewing conditions could be solved very soon. That fixation prediction performance is closely tied to object detection informs theories of attentional selection in scene viewing.

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26.4073 Reducing the central fixation bias: The influence of scene preview Lars Rothkegel[1](lrothkeg@uni-potsdam.de), Hans Trukenbrod[1], Heiko Schütt[1,2], Felix Wichmann[2,3,4], Ralf Engbert[1]; [1]Department of Psychology & Cognitive Sciene Program, University of Potsdam, [2]Deptartment of Computer Science, Neural Information Processing, Eberhard Karls University Tübingen, [3]Bernstein Center for Computational Neuroscience Tübingen, [4]Max Planck Institute for Intelligent Systems Tübingen

Models that aim at predicting fixation locations of observers in a natural scene can be based on assumptions on bottom up processes, top down processes, and systematic eye movement tendencies. Among the best predictors of fixation locations in an image is the distance of an image location from the image center. Because this central fixation bias (Tatler, 2007) is independent of image content, initial fixation position, screen or eye position, it is a very strong nuisance factor for scene viewing experiments under laboratory conditions. Scene preview from as short as 75 ms has been shown (Vo & Henderson, 2010) to influence saccade target selection effectively. Thus, a short scene preview might alter eye guidance during initial fixations and result in a reduced central fixation bias. In a scene viewing experiment, we manipulated the initial fixation position to keep the eyes for a certain amount of time fixated on one location before they were allowed to explore the scene freely for five seconds. As a result, we found that the central fixation bias was reduced for all pretrial fixation times from 125 ms to 1000 ms compared to a control group without scene preview. There were no systematic differences between the different pretrial fixation times. Our results have important practical implications for the evaluation of models of visual attention, since controlled initial fixation durations reduce attentional capture of the stimulus and, therefore, the central fixation bias.

26.4074 A Bayesian Model of Visual Question Answering Christopher Kanan[1](christopher.kanan@rit.edu), Kushal Kafle[1]; [1]Chester F. Carlson Center for Imaging Science, College of Science, Rochester Institute of Technology

Visual Question Answering (VQA) is a new problem in computer vision and natural language processing, with the first three English language datasets for VQA being released in the past year: DAQUAR, The VQA Dataset, and COCO-QA. In VQA, a model is given an image and a text-based question about a scene, and the model has to answer the question. The key insight in our model for VQA is that we can predict the form of the answer from the question. We formulate our model in a Bayesian framework, which has three multiplicative terms. The first predicts the form of the answer expected based on the question, e.g., if the question is, "What color is the bear?" it would model the probability of it being a color question. The second predicts the probability of the answer given the answer-type and the question. The third term predicts the probability of the observed visual features given the answer, answer-type, and the question. Our model shares similarities with visual attention, in that it directly models that the image features that should be attended directly depend on the task (question). We used a deep convolutional neural network for visual features, and use skip-thoughts to encode the questions. Our model achieved state-of-the-art results on all three benchmark datasets for open-ended VQA on real images beating the previous best by 14.9% (in relative terms) in the best case. While our results are good, there is still substantial room for improvement compared to humans when they are given the same images and questions.

26.4075 Retinotopic adaptation reveals multiple distinct categories of causal perception Jonathan Kominsky[1](jonathan.kominsky@yale.edu), Brian Scholl[1]; [1]Dept. of Psychology, Yale University

We can perceive not only low-level features of events such as color and motion, but also seemingly higher-level properties such as causality. Perhaps the best example of causal perception is the 'launching effect': one object (A) moves toward a stationary second object (B) until they are adjacent, at which point A stops and B starts moving in the same direction. Beyond the kinematics of these motions themselves, and regardless of any higher-level beliefs, this display induces a vivid impression of causality, wherein A is seen to cause B's motion. Do such percepts reflect a unitary category of visual processing, or might there be multiple distinct forms of causal perception? On one hand, the launching effect is often simply equated

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with causal perception more broadly. On the other hand, researchers have sometimes described other phenomena such as 'braking' (in which B moves much slower than A) or 'triggering' (in which B moves much faster than A). We used psychophysical methods to determine whether these labels really carve visual processing at its joints, and how they relate to each other. Previous research demonstrated a form of retinotopically specific adaptation to causality: exposure to causal launching makes subsequent ambiguous events in that same location more likely to be seen as non-causal 'passing'. We replicated this effect, and then went on to show that exposure to launching also yields retinotopically specific adaptation for subsequent ambiguous braking displays, but not for subsequent ambiguous triggering displays. Furthermore, exposure to triggering not only yielded retinotopically specific adaptation for subsequent ambiguous triggering displays, but also for subsequent ambiguous launching displays. Collectively, these results reveal that there is more to causal perception than just the launching effect: visual processing distinguishes some (but not all) types of causal interactions.

26.4076 **Binocular and monocular perception of 3D indoor scenes in a virtual environment** Eric Palmer[1](ewpalmer@purdue.edu), TaeKyu Kwon[1], Zygmunt Pizlo[1]; [1]Purdue University

Previous studies of figure-ground organization (FGO) used ambiguous 2D images. These stimuli contrast with our everyday experience where we view 3D scenes which are never ambiguous. In order to shed light on 3D FGO we tested the subject's ability to count pieces of furniture in 3D virtual scenes and to reconstruct their spatial arrangement. In the first experiment, the scene contained between 7 and 13 pieces of home and office furniture randomly arranged. In half of the scenes there were strong occlusions of some objects by others. Each of the 100 scenes was shown for 4 seconds. The subject's task was to count the objects. There were 3 experimental factors: monocular vs. binocular viewing, color vs. grey scale, and right side up vs. upside down scenes. The dependent variable was the error in the number of objects reported. The strongest effect was produced by the scene orientation. Binocular viewing produced better performance than monocular although this effect was small. Color had a negligible effect. In the second experiment, the subject's task was to reproduce the spatial positions and orientations of 6 pieces of furniture. The reconstruction room was viewed from a different angle compared to the reference room. Two angles were used, 22.5deg and 45deg. Viewing was monocular or binocular. Performance was very good, with most position errors being within the size of the furniture pieces. There was not much difference between monocular and binocular viewing. The rotation of the scene by 45deg was more difficult than 22.5deg. When the scene was upside down, the errors were twice as large. The presence of shadows did not affect performance. These results show that 3D scene perception is very good and that the effect of visual cues is weaker than the effect of a priori constraints such as the direction of gravity.

26.4077 **Change detection: the role of low-level versus high-level image representations** Wietske Zuiderbaan[1](w.zuiderbaan@uu.nl), Jonathan van Leeuwen[1], Serge Dumoulin[1]; [1]Experimental Psychology, Utrecht University, Netherlands

Introduction Our internal representation of an image is not as detailed as we intuitively experience. This is exemplified by the fact that subjects fail to detect large changes in a visual scene, i.e. change-blindness. Current theories propose that the internal representation captures the gist (interpretation of the image) and that changes in gist are detected faster. On the other hand, we know that early visual cortex represents contrast energy. Here we investigate the role of the low-level feature contrast and the higher-level feature gist on our internal representation. Methods We measured reaction times (RTs) in a flicker-task using the change-blindness paradigm (Rensink,1997). We alternated two images (108 image-sets) and the subjects (n=60) indicated when and where they saw the change. The images were taken from the Berkeley Segmentation Dataset and Benchmark database (Martin et al,2001). This dataset contains manual segmentations where subjects identified the most important aspects of the image. We use these segmentations as a measure of gist. For every image-set, we computed both the change in local RMS-contrast and the change in gist. From these changes we defined 4 conditions: image-sets that are 'low' and 'high' in their differences for contrast and gist, respectively. We controlled for size, eccentricity, local contrast and luminance of the changed area. Results RTs were faster when image-sets were high in gist change (median increase RT = 2.2sec), or high in contrast change (median increase RT = 1.75sec). Furthermore, RTs were fastest when image-sets were both high in gist change and high in contrast change (median increase RT = 5.0sec). Discussion Our results suggest that the internal representation of the image, as measured with a change-detection paradigm, is not only influenced by high-level image interpretation (gist), but also by low-level image statistics such as contrast.

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26.4078 **Where to Draw the Line: Effect of Artistic Expertise on Line Drawings of Natural Scenes** Heping Sheng[1](ann.sheng@mail.utoronto.ca), Dirk Walther[2]; [1]Department of Human Biology, University of Toronto, [2]Department of Psychology, University of Toronto

Humans are able to quickly and accurately recognize scenes from line drawings. This suggests that contour lines are sufficient to capture important structural information from a scene. Indeed, previous work from our lab has shown that viewing line drawings elicits similar neural activation patterns as viewing photographs, and that curvature and junction information is most helpful for human scene categorization. However, these results are based on line drawings made by one artist. In this study, we ask what contours and structural features are conserved across line drawings of scenes made by different people, and whether artistic expertise influences this consistency. We first developed software in Matlab Psychophysics Toolbox for tracing outlines over photographs of natural scenes (18 scenes, 6 categories) using a graphics tablet. Contours can be drawn free-hand or by creating a series of connected line segments. Spatial coordinates of the strokes are stored with temporal order information. Next we asked 43 participants with varying levels of artistic training to trace the contours in 5 photographs. We then extracted properties of contours (orientation, length, curvature) and contour junctions (types and angles) from each drawing. We found that people generally agree on some lines while differing on others. Specifically, contour curvature, orientation and junction types have the highest correlation between drawings of the same scene, across all scene categories, while contour length and junction angles are more variable between people. We are developing algorithms to determine matches between two individual drawings of the same image, and will present results showing which lines are most commonly agreed-upon, with characterization of the underlying physical phenomenon (occlusion boundaries, shadow, texture). In conclusion, our results measure the amount of agreement between individuals in drawing the contours in scenes. They highlight the importance of curvature and junctions for defining scene structure.

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Visual Search: Eye movements and memory

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4079 **How you use it matters: Object Function Guides Attention during Visual Search in Scenes** Monica Castelhano[1](monica.castelhano@queensu.ca), Qian Shi[1], Richelle Witherspoon[1]; [1]Queen's University

How do we know where to look for objects in scenes? While it is true that we see objects within a larger context daily, it is also true that we interact with and use objects for specific purposes (object function). Many researchers believe that visual processing is not an end in itself, but is in the service of some larger goal, like the performance of an action (Gibson, 1979). In addition, previous research has shown that the action performed with an object can affect visual perception (e.g., Grèzes & Decety, 2002; Triesch et al., 2003). Here, we examined whether object function can affect attentional guidance during search in scenes. In Experiment 1, participants studied either the function (Function Group) or features (Feature Group) of a set of invented objects. In a subsequent search, studied objects were located faster than novel objects for the Function, but not the Feature group. In Experiment 2 invented objects were positioned in either function-congruent or function-incongruent locations. Search for studied objects was faster for function-congruent and impaired for function-incongruent locations relative to novel objects. These findings demonstrate that knowledge of object function can guide attention in scenes. We discuss implications for theories of visual cognition, cognitive neuroscience, as well as developmental and ecological psychology.

26.4080 **People with Schizophrenia Demonstrate More Optimal Feature-Guided Visual Search in a Probabilistic Search Task** Valerie Beck[1](valerie-beck@uiowa.edu), Carly Leonard[2], Benjamin Robinson[3], Britta Hahn[3], Andrew Hollingworth[1], James Gold[3], Steven Luck[2]; [1]Department of Psychological and Brain Sciences, University of Iowa, [2]Center for

Mind and Brain and Department of Psychology, University of California, Davis, [3]Maryland Psychiatric Research Center, University of Maryland School of Medicine

Recent research suggests that people with schizophrenia (PSZ) tend to hyperfocus on goal-relevant information, which is typically deleterious to task performance. However, performance decrements can be difficult to interpret because many different factors can lead to impaired performance. Here we show that hyperfocusing on goal-relevant information can actually lead to a more optimal pattern of attentional guidance during visual search in PSZ than in healthy control subjects (HCS). We recorded eye movements during a visual search task in which participants searched for a Landolt-C target in a 24-item array (12 red and 12 blue items), and we varied the probability that the target was a cued color (100%, 80%, or 50%) versus an uncued color (0%, 20%, or 50%). When the target was more likely to be one color than the other (80% valid cue), both groups tended to fixate multiple items of the cued color before switching to the uncued color, but this pattern was stronger in PSZ than in HCS. In other words, PSZ tended to maintain the goal of searching the cued color longer than did HCS. Comparison of the participants' search patterns against those generated using Monte Carlo analyses revealed that the pattern in PSZ was closer to optimal than the pattern in HCS. Furthermore, fixating a greater number of cued color items was associated with faster target detection in both groups. These results cannot be explained by a generalized cognitive impairment in PSZ, but instead reflect a specific alteration of cognitive processing in schizophrenia that can lead to more optimal performance under some conditions.

26.4081 **Simple actions influence eye movements** Jihyun Suh[1](jihyun.suh@wustl.edu), Blaire Weidler [1], Richard Abrams[1]; [1]Psychological and Brain Sciences, Washington University in St.Louis

Recent research has revealed that action can have an influence on visual perception. For example, participants find targets more quickly in a visual search task when the target is associated with a feature they previously acted towards. However, all evidence for this phenomenon comes from manual response time data. Thus, it is theoretically possible that action's effect is not on perception but instead on post-perceptual response processes. Here for the first time we investigated if a prior action can affect oculomotor behavior. In two experiments participants saw a word pre-cue followed by a colored shape. Participants either made an action (pressed the space bar) or simply viewed the shape depending on the match between the pre-cue and the shape's color (Experiment 1) or on the identity of the pre-cue (Experiment 2). Next, two circles with embedded lines appeared; participants' task was to find and indicate the tilt of the sole tilted line. Although color was irrelevant to the search task, one of the circles was the color of the earlier seen shape; on half of the trials it contained the target and on half the distractor. Both experiments replicated the typical "action effect" pattern: Participants were faster to find the target if it was in the color they saw earlier in the trial, but only following an action (i.e., although irrelevant to the task, the acted-on color received priority in visual search). Importantly, oculomotor behavior was also affected by prior action in both experiments—after an action (but not after viewing) participants' first saccade was directed to the target more often when it was in the color of the acted-on object than when that color contained a distractor. Overall the results show for the first time that a prior arbitrary action affects eye movements.

26.4082 **Neither Ideal behaviour nor Bounded Rationality Account for Human Visual Search Performance** Alasdair Clarke[1](a.clarke@abdn.ac.uk), Anna Nowakowska[1], Amelia Hunt[1]; [1]School of Psychology, College of Life Sciences and Medicine, University of Aberdeen

Imagine that you are searching for a red pen, and you know it could be on either of two desks. The top of one desk is clean, while the other desk is cluttered with papers, books and coffee cups. Common sense suggests an efficient visual system would not waste any time on the clean desk. Here we test whether optimal fixation strategies can be employed using an analogous experimental setup: stimuli consisting of arrays of line segments, homogenous on one half, and heterogeneous on the other. Using peripheral vision only, observers could accurately detect whether there target was present or absent in the homogeneous but not the heterogeneous array. If search is optimal, the proportion of fixations directed to the heterogeneous side on any given trial should be approximately one. One out of the 14 observers in this experiment followed this strategy, but the rest did not. Individual differences in the relative proportion of fixations on the homogenous vs. heterogeneous side during the first five fixations on target absent trials were highly correlated with how quickly observers detected the target when it was present, both for the heterogeneous ($r=0.91$, $p< 0.001$) and homogeneous ($r=0.79$, $p=0.001$) side of the display. This correlation clearly demonstrates that observers who have a tendency to search the homogenous side were slower to find the target when it was present. In a follow-up experiment, we directly compared search of uniform homo- and heterogeneous arrays to search of half homo-half heterogeneous. Reaction time should be the average of RT on the two uniform displays, but observers actually take 20% longer than predicted ($t(13)=30.95$, $p< 0.001$). Together the results suggest superfluous fixations are directed to the homogeneous side, inconsistent with optimal search.

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26.4083 **Exploring the nature of mental representations in hybrid visual and memory search** Jessica Madrid[1](cyrene@nmsu.edu), Corbin Cunningham[2], Arryn Robbins[1], Hayward Godwin[3], Jeremy Wolfe[4], Michael Hout[1]; [1]New Mexico State University, [2]Johns Hopkins University, [3]University of Southampton, [4]Brigham & Women's Hospital/Harvard Medical School

To search for targets in scenes filled with distractors, observers must utilize mental representations ("templates") for those targets (e.g. where are my keys). While previous research on "hybrid search" has demonstrated that observers can search for any of hundreds of distinct targets, little is known about the internal representation of those targets. Is each target stored individually or can related targets form prototypes that speed search? To address this question, observers performed hybrid search for a memory set of 30 target types in two conditions (blocked, counterbalanced order). In the "categorical" condition, observers searched for footwear and strollers. A small category was defined by five exemplars of either footwear or strollers; a large category, by 25 of the other. In the "mixed" condition, target types were drawn from 30 different categories. Five were arbitrarily assigned to a "small" artificial category and 25 to a "large" category. After the pictures were memorized, observers searched for any of the 30 targets (160 trials, 50% target present). Distractors came from various categories that did not overlap with any targets. Reaction times were faster in the categorical condition; unsurprising, since observers needed only to determine if an item was footwear or a stroller. More interestingly, RTs were faster for the larger category (even after controlling for prevalence: 3175 ms vs 3481ms). This effect was reduced for the mixed condition. We hypothesize that, with natural categories, 25 exemplars allowed observers to create a more useful prototype than just five exemplars. This effect is minimal or absent with artificial, arbitrary categories; at least given the level of practice experienced by our observers. Overall, this work demonstrates that, when searching for a set of items within a given category, the utility of a prototype is dependent on the number of items used to form that prototype.

26.4084 **Paradoxical speeding of visual search by the inclusion of WM and LTM lures** Beatriz Gil-Gómez de Liaño[1](bgil.gomezdeliano@uam.es), Trafton Drew[2], Daniel Rin[1], Jeremy Wolfe[3]; [1]Universidad Autónoma de Madrid, [2]University of Utah, [3]Harvard Medical School & Brigham & Women's Hospital

There is extensive empirical evidence that Working Memory (WM) representations can bias selection in Visual Search (VS) tasks (reviewed in Soto & Humphreys, 2014). Less has been said about the guidance of attention in VS by the contents of Long Term Memory (LTM), but some studies have shown effects from LTM representations on VS (e.g. Olivers, 2011). As a general rule, when an item to be held in WM or LTM appears as a 'lure' in the visual search display, search is slowed. Here we report conditions under which search is actually speeded by the presence of lures. Fourteen observers searched for a different target on every trial. Targets and distractors were photographs of objects. Observers held either 10 or 32 items in LTM and another item was presented before each trial to be held in WM. A true target was present on every trial. The VS display of 16 items could also contain a WM lure, a LTM lure, both, or none. Observers localized the target with a mouse-click. Under these conditions, RTs were generally faster when lures were present. This was particularly evident when both LTM and WM lures were present. We speculate that this represents a type of familiarity effect. The target is new on each trial and, thus, not very familiar. The lures are more familiar. A rule that rapidly rejects familiar items could speed search if lures can be quickly rejected and might speed search more when two lures can be rejected. This effect is not seen when targets are not present on every trial. Lures tend to slow search in those conditions, perhaps because any familiarity becomes a sign of possible target presence when target presence is uncertain. Both the speeding and slowing of search show the influence of memory on search.

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26.4085 Long-Term Priming Prevails Against the Passage of Time and Countermanding Instructions Wouter Kruijne[1](w.kruijne@vu.nl), Martijn Meeter[1]; [1]Vrije Universiteit Amsterdam

Studies on intertrial priming have shown that in visual search experiments, the preceding trial automatically affects search performance: facilitating it when the target features repeat, and giving rise to switch costs when they change. These effects also occur at longer time scales: when one of two possible target colors is more frequent during an experiment block, this results in a prolonged and persistent facilitation for the color that was biased, long after the frequency bias is gone. In this study, we explore the robustness of such long-term priming. In one experiment, long-term priming was built up in one experimental session, and was then assessed in a second session a week later. Long-term priming persisted across this week, emphasizing that long-term priming is truly a phenomenon of long-term memory. In another experiment, participants were fully informed of the bias and instructed to prioritize the other, unbiased color. Nevertheless, long-term priming of the biased color persisted in this block. The results support the view that priming results from the automatic and implicit retrieval of memory traces of past trials.

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26.4086 Working Memory Capacity Predicts Two Causes of Increased Accuracy in Visual Search Chad Peltier[1](peltie11@gmail.com), Mark Becker[1]; [1]Michigan State University

There are two potential causes of missed targets in visual search tasks: search errors, where the target is never inspected before making a response, and recognition errors, where the target is fixated, but goes unrecognized. Search errors increase with low quitting thresholds; too few items are inspected to reliably find the target. Recognition errors are due to a poor decision process that evaluates whether each scrutinized item is a target or not (and could be due to a conservative criterion, poor evidence accumulation, or a poor search template), resulting in a greater chance of the item failing to reach the target threshold (Wolfe & Van Wert, 2010). Though high working memory has been found to predict greater accuracy in visual search tasks (Schwark, Sandry, & Dolgov, 2013), it is unknown whether the source of this improvement is higher quitting thresholds, better item-by-item decisions, or both. To investigate this issue, eye movements were tracked during a visual search task for a target T among Ls. Following eye-tracking, working memory capacity (WMC) was measured using a change detection task (Luck and Vogel, 1997). We correlated WMC with accuracy, number of items inspected before terminating a trial, and target recognition rate in the visual search task. Results show that working memory is positively correlated with hit rate, replicating previous research. We extend these results by showing higher working memory predicts both an increase in the number of items inspected per trial and a decrease in recognition errors, indicating higher quitting thresholds and better item-by-item decision making. These results could potentially be used to inform screening of new employees whose jobs will be to detect targets in a visual search, such as in the Transportation Security Administration.

26.4087 Visual search for changes in scenes creates long-term, incidental memory traces Igor Utochkin[1](isutochkin@inbox.ru), Jeremy Wolfe[2,3]; [1]National Research University Higher School of Economics, Moscow, Russia, [2]Visual Attention Laboratory, Brigham & Women's Hospital, Cambridge, MA, USA, [3]Harvard Medical School, CambridgeBoston, MA, USA

Humans are very good at remembering large numbers of scenes over substantial periods of time. How good are they at remembering changes to scenes? In this study, we compared the long-term effect on scene memory and subsequent change detection of a previous visual search for change compared to intentional memorization of scenes. First, participants either performed a change detection task in natural scenes or explicitly memorized those scenes. Two weeks later, they were shown single scenes and asked if they were old or new. Then they were asked to recall changes (if the initial task was change detection) or to detect a change between the initial and current presentations (if the initial task was memorization). Finally, they searched for that change by alternating between the two versions of the scene. Incidental memory for the scenes, viewed during an initial change blindness was the same as memory after intentional memorization (~67-70% correct recognition and ~13-15% false recognition), with better memory for scenes where changes had been found. Unsurprisingly, observers were fast to find the change the second time if they remembered the change. More surprising, observers were faster to find changes that they had previously found but did not remember finding. This result was replicated in two of three change detection experiments. Time required to find changes in the first and second phases of the experiment were correlated in scenes where the observers didn't remember the change, perhaps showing some similarity between search strategies. Observers showed better memory for changes that had been hard to find. Control experiments rule out boring accounts for this effect (e.g. initial exposure duration). We conclude that scenes can be encoded incidentally as well as explicitly and that changes in those scenes can leave measurable traces even if they are not explicitly recalled.

26.4088 Does attention look to visual working memory for guidance when we are about to search for something new? Travis Weaver[1](travis.p.weaver@vanderbilt.edu), Geoffrey Woodman[1]; [1]Department of Psychology, Center for Integrative and Cognitive Neuroscience, Vanderbilt Vision Research Center, Vanderbilt University,, Nashville, Tennessee 37240, USA

Theories of visual attention claim that representations in visual working memory (VWM) are able to control attention as we search for targets embedded in arrays of other objects. However, recent findings have shown that VWM is only used to control attention when the target is new, whereas long-term memory (LTM) takes control of visual attention after a handful of trials searching for a certain target. This study tested whether VWM would take the control of attention back from LTM if participants were expecting to search for a new target. The task was a visual search task in which participants were shown a target item (a Landolt-C) for 250 ms. After a 900 ms delay, an array of items was presented. Participants were instructed to respond with a button press indicating if the target item was present or absent. The key manipulation was the number of consecutive trials that subjects would be cued to search for the same target. On 75% of same-target runs, the subjects searched for the same object for 4 trials, with only 25% of same-target runs being 5 trials long. As a result, subjects should expect VWM to need to take back attentional control after 4 trials. We used the contralateral delay activity (CDA) and the anterior P1 (or P170) component as a measure of whether the target was stored in VWM or LTM. These event-related potentials replicated previous studies, showing a trade off of attentional control from VWM to LTM during the first four trials. Contrary to the prediction that VWM would take attention control back from LTM when a target change was likely, we found no change in reaction time, CDA, or P170 amplitude between trials 4 and 5. In summary, participants do not switch back to using VWM to control attention until absolutely necessary.

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26.4089 Contrasting Gist-based and Feature-based Guidance during Real-world Search Brett Bahle[1](brett-bahle@uiowa.edu), Andrew Hollingworth[1]; [1]University of Iowa

Visual search in traditional, abstract arrays is typically dominated by feature guidance. In contrast, search in natural scenes is thought to be dominated by scene-level guidance, both semantic (knowledge of the plausible regions where an object might be found) and episodic (knowledge of where a specific exemplar is located). Wolfe et. al (2011) proposed a two-pathway architecture for search in scenes. The dominant pathway is 'nonselective' and utilizes scene-level guidance, derived from gist recognition, to direct attention to plausible regions. The secondary 'selective' pathway uses feature guidance to further narrow search. However, this claim of a hierarchal relationship (initial gist-based guidance, followed by local feature guidance) has not been tested directly. The present study investigated this relationship, and we hypothesized that feature guidance plays a more substantial and earlier role than currently theorized. We placed scene-level guidance in conflict with feature guidance from a search-task-irrelevant color maintained in visual working memory (VWM). Participants searched for a letter superimposed on an object in a natural scene, receiving no cue, a word cue, or a picture cue for the target object. Simultaneously, they maintained a color in VWM for a later memory test. Half of the scenes contained a distractor object with a color that either matched or mismatched the remembered color. Search times declined with increasing cue specificity. Importantly, under all conditions of guidance, participants were more likely to fixate the distracting object on match compared with mismatch trials, increasing search times. This feature-based capture was most pronounced during the first few saccades on the scene. Moreover, capture occurred even on trials where the distracting object appeared in an implausible location for the target. These results imply a substantial role for feature guidance in the earliest stages of real-world search. Search through natural scenes is not necessarily dominated by gist-based guidance.

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26.4090 **Rapid resumption of interrupted visual search in autism**

Owen Parsons[1](oep20@cam.ac.uk), Jan Freyberg[1], Simon Baron-Cohen[1]; [1]Autism Research Centre, Department of Psychiatry, University of Cambridge

Introduction: Visual perception is influenced by prior experiences and learned expectations. One example of this is the ability to rapidly resume visual search after an interruption to the stimuli. It has recently been suggested that atypical visual perception in autism spectrum conditions (ASC) can be explained by attenuated use of prior information during perception. However, there is a current lack of empirical evidence to comprehensively evaluate this theory. Objectives: We aimed to use an interrupted search paradigm to assess whether rapid resumption is intact in ASC. We hypothesize that attenuated use of prior information in perception would lead to a reduced ability to rapidly resume searches after interruption. Methods: Participants with (N=18) and without ASC (N=20) were asked to complete a visual search task in which search displays were periodically interrupted by blank displays. Participants were required to locate a 'T' shaped target amongst 'L' shaped distractors and to report its color. Search displays contained either 16 or 32 distractors. During trials the search display would only be visible for 100ms presentations separated by a 900ms blank display. Participants completed a total of 300 trials, divided across 10 blocks. Results: Reaction time distributions were normalized separately for responses occurring between the first and second exposures of displays and responses occurring after subsequent exposures. Distributions were compared using Chi-squared tests. In both groups the distribution of responses immediately following the first exposure differed significantly from the distribution of responses following subsequent exposures (p< .001). We found no difference in the distributions of responses occurring following subsequent exposures between the two groups (p>.250). Discussion: Out results suggest that rapid resumption is unimpaired in ASC. These findings are in contrast to the hypo-priors account, suggesting that prior information is used normally by individuals with ASC during visual search.

Visual Memory: Encoding, retrieval

Saturday, May 14, 2:45 - 6:45 pm
Poster Session, Pavilion

26.4091 **Is encoding into visual working memory a serial process?**

Edwin Dalmaijer[1](edwin.dalmaijer@psy.ox.ac.uk), Masud Husain[1,2]; [1]Department of Experimental Psychology, University of Oxford, Oxford, United Kingdom, [2]Nuffield Department of Clinical Neuroscience, University of Oxford, Oxford, United Kingdom

Visual Working Memory (VWM) is a highly limited resource that we use to temporarily store information on items that we encounter. How different items are encoded into VWM remains unclear. Some think individuals can encode multiple items in parallel. An alternative idea is that encoding is serial, with only one item being processed at a time. We used a whole report task in which participants were asked to remember a single or two coloured patches simultaneously. The stimuli were shown for various durations (ranging from 0 to 580ms), and were masked directly after. Participants sequentially indicated the colours they remembered on two continuous colour wheels. We modelled the distributions of errors (as a function of exposure duration) with a mixture model of VWM components, quantifying how much VWM resource was devoted to each stimulus. This demonstrated that the colours' VWM representations improved with exposure duration, and were better for one than for two stimuli. Crucially, we analysed response error as a function of response order. This yielded no difference between error for a single-item response and for the first of the two-item responses. In addition, we modelled the probabilities of individuals remembering none, only one, or both of the simultaneously presented items. Initially, participants were highly likely to remember only one stimulus (at 70ms), but with higher exposure durations (from 200ms) participants were more likely to remember both. Our results are in line with serial encoding into VWM, with one item (or location occupied by an item) being encoded first, followed by the second.

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26.4092 **Distinct roles of eye movements during memory encoding and retrieval**

Claudia Damiano[1](claudia.damiano@mail.utoronto.ca), Dirk Walther[1]; [1]Department of Psychology, University of Toronto

Eye movements help to facilitate memory for complex visual scenes. Here we ask whether the benefit of eye movements for memory is stronger during the encoding phase or the recognition phase. 20 participants viewed photographs of real-world scenes, followed by a new-old memory task. They were either allowed to freely explore the scenes via eye movements in both the study and test phases (Condition S+T+), or had to refrain from making eye movements in either the test phase (Condition S+T-), the study phase (Condition S-T+), or both (Condition S-T-). Recognition accuracy (d-prime) was significantly higher when participants were able to move their eyes (Condition S+T+: 1.16) than when they were constrained in some way (Condition S+T-: 0.67, Condition S-T+: 0.42, Condition S-T-: 0.35, p < 10-6). A separate analysis on Hit rates and False Alarm rates indicates a dissociation between the effects of eye movements on memory during the study and test phases. The Hit Rate was greatly influenced by the ability to make eye movements during the study phase, while the False Alarm rate was affected by whether participants could make eye movements during the test phase. Taken together, these results suggest that eye movements during the first viewing of a scene, used to visually explore and encode the scene, are critical for accurate subsequent memory. Eye movements during the test phase, on the other hand, are used to re-explore the scene and to confirm or deny recognition. Thus, eye movements during both the first encounter and subsequent encounters with a scene are beneficial for recognition through proper exploration, encoding, and re-exploration of the visual environment.

26.4093 **Changes in task-irrelevant context invoke updating of task-relevant representations in working memory**

Emma Wu Dowd[1](emma.wudowd@duke.edu), Eren Gunseli[1,2,3], Martijn Meeter[2], Christian Olivers[2], Tobias Egner[1]; [1]Duke University, [2]Vrije Universiteit, Amsterdam, Netherlands, [3]University of Chicago

Working memory (WM) involves the active maintenance of information necessary for ongoing tasks, such that task-relevant changes in the environment trigger the dynamic updating of representations within WM. Long-term memory is strongly affected by context (i.e., aspects of the environment that are not directly task-relevant), but how is WM impacted by context changes? We hypothesized that changes in task-irrelevant context are automatically encoded into WM, resulting in WM updating for task-relevant memory representations. To examine behavioral and neural effects of task-irrelevant changes on WM updating, we collected fMRI data during a delayed matching task. Participants remembered a tilted Gabor patch across a 10s delay for a two-alternative-forced-choice memory test. These target patches were superimposed on a face or house image, serving as task-irrelevant context (only during cue display, not at test). Critically, we independently varied repetitions and changes of both targets and context cues, resulting in factors of task-relevant (target-new, target-old) and task-irrelevant (context-new, context-old) changes. Multivariate pattern analyses were used to track active neural representations of targets, to test whether context changes triggered WM updating for the target representations. Neural representations of both targets and context cues were successfully decoded from ventral visual and temporal cortex during the delay. When context did not change, behavioral memory performance improved with increasing target repetitions, whereas neural decoding accuracy decreased, suggesting that learning of the memory target resulted in less active maintenance. Context repetition did not affect memory performance, but classification accuracy for the target increased for context changes. Importantly, when context changes occurred late in the target repetition sequence (i.e., target-old/context-new), memory performance dropped while decoding strength peaked, consistent with re-activation of the repeated target representation in WM. These findings indicate that not only are context changes automatically encoded, but this task-irrelevant updating also re-invokes WM updating for the task-relevant target.

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26.4094 **Of "What" and "Where" in a natural search task: Active object handling supports object location memory beyond the objects' identity**

Dejan Draschkow[1], Melissa Vo[1]; [1]Scene Grammar Lab, Goethe University Frankfurt

In natural behavior, cognitive processes are strongly intertwined with observers' active interaction with the environment. To what degree does actively manipulating objects modulate memory representations of these objects? In a real world paradigm (fully furnished four-room apartment) we investigated if physically engaging with objects as part of a search task differentially influences identity and position memory for objects that are either relevant or irrelevant to a given task. Participants (N = 16) equipped with a mobile eye tracker either searched for cued objects without object interaction (Passive condition) or actively collected the objects they found

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(Active condition). Additionally, a unique category of objects was designated as relevant for each room (e.g. "objects needed for making a sandwich" in the kitchen) and participants were instructed to decide if an object was relevant upon finding it. In a subsequent, unannounced free recall task, identity memory was assessed demonstrating superior memory for relevant compared to irrelevant objects, but no difference between the Active and Passive condition. Finally, location memory was inferred via times to first fixation in another object search task. Again, there was no overall difference between the Active and Passive condition, yet location memory for relevant objects was superior to irrelevant ones only in the Active condition. This implies that active object manipulation interacts with task-relevance. Including identity memory performance in the recall task as a covariate in the linear mixed-model analysis of times to first fixation allowed us to explore the interaction between remembered/forgotten object identities and location memory performance for these. Strikingly, identity memory performance predicted location memory in the Passive, but not the Active condition. Together, these results suggest that active object handling leads to a prioritization of task relevant information and a strengthening of location representations above and beyond object identity memory performance.

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26.4095 **Acquisition and persistence of location information over the time course of natural actions.** M Pilar Aivar[1](mariapilar.aivar@uam.es), Chia-Ling Li[2], Matthew Tong[3], Dmitry Kit[4], Mary Hayhoe[3]; [1]Facultad de Psicología, Universidad Autónoma de Madrid, Spain, [2]Institute for Neuroscience, The University of Texas at Austin, US, [3]Center for Perceptual Systems, The University of Texas at Austin, US, [4]Department of Computer Science, University of Bath, UK

Previous research has shown that information that is task-relevant is retained over time and protected from posterior interference (e.g. Maxcey-Richard & Hollingworth, 2013). To examine whether location information is acquired and persists over the time course of natural actions we had participants perform a visual search task in an immersive virtual reality apartment. Participants searched the two rooms that formed the apartment for a series of geometric target objects, which were always visible. Eye movements, head movements and body trajectories were recorded. Target locations were manipulated to see if participants took advantage of regularities in the environment. Specifically, all target objects (8) were presented at the same locations in blocks 1, 2, 3 and 5, but switched location in each trial during block 4. We analyzed search time and number of errors (visits to wrong room) per block of 8 trials. Average search time decreased significantly between blocks 1 and 3 and then increased significantly in block 4. Interestingly, search time decreased again in block 5, once objects returned to their locations, with averages significantly lower than those of block 3. Room errors increased to 50% in block 4 but decreased significantly in block 5 to values similar to those of block 3. Gaze content also showed that about half of the participants used a memory-based strategy for finding the objects in block 4: on 28% of the trials these participants' first object fixation was on the object now occupying the location where the target used to be in blocks 1 to 3. From these three results we conclude that participants retained target location information from previous trials and used this information to make their search more efficient (i.e. block 5). The unreliability of object locations during block 4 was not enough to overwrite the information acquired during the first three blocks.

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26.4096 **Investigating human memory of self-position using a virtual 3-dimensional visual environment** Celia Gagliardi[1](gagliard@bu.edu), Arash Yazdanbakhsh[1,2]; [1]Center for Computational Neuroscience and Neural Technology, Boston University, [2]Department of Psychological and Brain Sciences, Boston University

Knowing one's location in space is crucial for navigation, especially in unknown environments. Recently, systems involved in self-localization for spatial navigation have been found in rodent brains, but the mechanisms for self-localization are not completely understood. Human behavioral experiments can enhance understanding of self-localization systems in human brains. In this study, human observers are placed in a visual virtual reality (VR) to perform a self-positioning task. The VR is created using a 120 Hz projector and a polarizing filter which separates left and right eye images when passed through 3D glasses. Disparity and size cues generate the perception of depth. Participants are placed in a virtual position on the ground for five seconds and then moved by changing their virtual environment around a stable object. Their task is to return to their initial position on the ground with button controls. Principal component analyses show that errors in self-repositioning are not along any particular axes and each participant has a unique pattern of repositioning. Trial durations do not affect accuracy of repositioning and lack of disparity cues increases the standard error of repositioning in all directions. Some participants have lower errors when initial self-positions appear to be on one or the other side of the stable object, suggesting a link between memory of self-position and a preferred point of reference. Future directions of this project are to explore between-subject differences and the effect of stimulus presentation at different frequencies on memory of self-position.

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26.4097 **Attending and Inhibiting Stimuli That Match the Contents of Visual Working Memory: Evidence from Eye Movements and Pupillometry** Sebastiaan Mathôt[1](s.mathot@cogsci.nl), Elle Van Heusden[2], Stefan Van der Stigchel[2]; [1]Aix-Marseille University, CNRS, LPC UMR 7290, Marseille, France, [2]Dept. of Experimental Psychology, Helmholtz Institute, Utrecht University, The Netherlands

When you keep a red apple in working memory, your attention is usually—but not always—attracted by other red objects. The conditions under which the contents of visual working memory guide visual attention are still unclear. We conducted two experiments to test whether attention is indeed biased toward memory-match stimuli, and, if so, whether this bias is transient or sustained. We used a new pupillometric technique, which exploits that the pupil is larger when you covertly attend to dark, compared to bright, stimuli. This allowed us to test whether and when attention was biased toward memory-match stimuli, by placing them either on a dark or a bright background, while measuring pupil size over time. In addition, we looked at gaze errors, that is, whether and when participants looked at memory-match stimuli (despite instructions to maintain central fixation). We found that the eyes were captured by memory-match stimuli early on in the trial. However, the pupillary data suggested that there was no sustained attention bias toward memory-match stimuli later in time; rather, attention appeared to be biased away from them. Together, our results suggest that: (1) memory-match stimuli automatically capture attention; but (2) they do so only briefly; and (3) they may even become inhibited later in time.

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26.4098 **Constraints on Information Compression in Visual Working Memory** Hrag Pailian[1](hrag.pailian@gmail.com), Elizabeth Tran[1], George Alvarez[1]; [1]Harvard University

In standard working memory tasks, people can remember ~3 random colors. However, when colors are highly correlated (e.g., red often appears next to blue), people learn these regularities and use them to store more items in memory (Brady, Konkle, Alvarez, 2009). This learning occurs even when participants do not notice the correlation, and is consistent with a model in which participants optimally compress redundant information. Here, we investigated whether the efficiency of learning and information compression is constrained by 1) the number of to-be-compressed color pairs, and 2) the amount of feature overlap across these color pairs. Participants saw displays of 8 colors, arranged into 4 concentric pairs (e.g., a red ring with a blue circle in the middle). Certain color pairs co-occurred more frequently than others (high-probability pairs, HPPs). In Experiment 1, 80% of the color pairs in each display were high-probability pairs, chosen from a set of 4 possible HPPs for one group of subjects, and 8 possible HPPs for another group. We measured performance across blocks of trials (10 blocks x 60 trials), then modeled learning rates (α) using a Bayesian model, and compression using Huffman coding. The model results suggest that each group learns at a similar rate (4-HPP-group, α=.31, model fit r=-.70; 8-HPP-group α=.36, model fit r=-.65). In Experiment 2, we replicated the 8HPP condition, but for this group colors could repeat across pairs. For example, one HPP pair might have red-outside/blue-inside, and another might have red-outside/green-inside. Learning rates for this group were slower (α=.50, model fit r=-.63), even though the total amount of information stored was not different across groups (p=.53). Combined, these results suggest that it is possible to learn and compress information across many items, but that feature overlap amongst those items can reduce the efficiency of learning and compression.

26.4099 Episodic short-term recognition presupposes visual working memory: Findings from combined probe recognition and letter report Christian Poth[1,2](c.poth@uni-bielefeld.de), Werner Schneider[1,2]; [1]Department of Psychology, Bielefeld University, Bielefeld, Germany, [2]Cluster of Excellence Cognitive Interaction Technology (CITEC), Bielefeld University, Bielefeld, Germany

Visual perception is structured in discrete processing episodes (e.g. eye fixations or task-steps). Object information must be transmitted across episodes to enable episodic short-term recognition: recognizing whether a current object has been seen in a previous episode. We ask whether episodic short-term recognition presupposes that objects have been encoded into capacity-limited visual working memory (VWM), which retains visual information for report. Alternatively, it could rely on the activation of visual features or categories which happens before encoding into VWM. We assessed the dependence of episodic short-term recognition on VWM by a new paradigm combining letter report and probe recognition. Participants viewed displays of ten letters and reported as many as possible after a retention interval (whole report). Next, participants viewed a probe letter and indicated whether it had been one of the ten letters (probe recognition). In Experiment 1, probe recognition was more accurate for letters encoded into VWM (reported letters) compared with non-encoded letters (non-reported letters). Interestingly, reported letters had been near to each other within letter displays, suggesting spatially clustered encoding into VWM. Therefore, in Experiment 2 participants reported only one of ten letters (partial report) and probes either referred to this letter, to letters that had been near to it, or far from it. Probe recognition was more accurate for near than for far letters, although none of these letters had to be reported. These findings indicate that episodic short-term recognition is constrained to a small number of simultaneously presented objects that have been encoded into VWM.

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26.4100 To OBE or Not To OBE? Revisiting Object-based Encoding (OBE) in in Visual Working Memory Rende Shui[1](rshui@zju.edu.cn), Shixian Yu[1], Ying Zhou[1], Mowei Shen[1], Peng Li[1], Zaifeng Gao[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

It has been suggested that visual working memory (VWM) adopts an object-based encoding (OBE) manner to extract perceptual information into VWM. That is, whenever even one feature-dimension is selected for entry into VWM, the others are also extracted automatically. Almost all extant studies revealing OBE were conducted by probing an "irrelevant-change distracting effect", in which a change of stored irrelevant-feature dramatically affects the change detection performance of the target feature. However, the existence of irrelevant feature change may affect the participants' processing manner, leading to a false positive result. In the current study, we conducted a strict examination of OBE in VWM, by keeping the irrelevant feature of the memory item constant while probing whether task-irrelevant feature can guide the early deployment of attention in visual search. In particular, we required the participants to memorize an object's color while ignoring shape. Critically, we inserted a visual search task into the maintenance phase of VWM, and the participants searched for a target line among distractor lines, each embedded within a different object. One object in the search display could match the shape, the color or both dimensions of the memory item, but this object never contained the target line. Relative to a neutral baseline (no match between the memory and the search displays), we found that the search time was significantly prolonged in all the three match conditions. Moreover, this pattern was not modulated by the exposure time of memory array (100 or 1000ms), suggesting that similar to the task-relevant feature color, the task-irrelevant shape was also extracted into VWM, and hence affected the search task in a top-down manner. Therefore, the OBE exists in VWM.

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26.4101 Signal to source assignment as a fundamental constraint on visual working memory Jonathan Flombaum[1](flombaum@jhu.edu), Zheng Ma[1]; [1]Psychological and Brain Sciences, Johns Hopkins University

A serious computational problem faced by human vision is to assign signals to sources. Received signals come from a priori unknown sources and the same signal content must be used to infer the presence of objects, to assign causal responsibility for individual signals to particular objects, and to infer the properties of those objects. Research on visual working memory often takes for granted signal to source assignment. We investigated assignment empirically through a modification to the color delayed estimation task: participants encoded the colors of a set of squares. After a delay, in half of trials, they reported as precisely as they could the color of a probed square. In 25% of trials, they were asked only to click in every location they remembered an object, and in 25% they reported the number of objects seen. In both the latter conditions, numerical reports showed significant variability, increasing with more objects. These results suggest that segmenting a display into the right number of objects is not always accomplished accurately. We used a clustering model to relate these results more directly to assignment. The model received fifty noisy samples from each object in a memory display. Samples were distributed spatially with eccentricity-dependent Gaussian variance and in color space following a von Mises centered on the color of each source object. The model then used a modified DBSCAN algorithm to cluster samples, effectively identifying samples thought to share a source. Finally, the model reported the number of clusters identified, their centroids, and an estimate of the source color for each cluster. Responses were significantly correlated with those of human observers. These results suggest that using visual working memory involves uncertainty about the association between received signals and their possible sources, uncertainty that places independent constraints on human capabilities.

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26.4102 Interplay between the Ebbinghaus illusion and hierarchical coding in visual working memory Vladislav Khvostov[1](hvo100v@mail.ru), Igor Utochkin[1], Hee Yeon Im[2]; [1]1National Research University Higher School of Economics, Moscow, Russia, [2]Department of Radiology, Harvard Medical School / Massachusetts General Hospital, Charlestown, USA

It was shown that recalled size of an individual item is systematically biased towards the mean size of a set (Brady & Alvarez, 2011), suggesting hierarchical encoding in visual working memory (VWM). Yet, we also observe somewhat opposite trend in perception: perceived size of a circle, surrounded by other circles, is biased away from the mean (e.g., Ebbinghaus illusion). Here we examined the interplay between different biases elicited by perceptual illusion and hierarchical reorganization in VWM. We presented observers with four target circles of different sizes for 2 seconds, followed by a 1-second blank interval, and asked them to recall a size of a probed target circle. In the congruent-bias condition, two smallest target circles were surrounded by even smaller inducers and two largest target circles were surrounded by bigger circles. In this condition, both perceptual illusion and VWM encoding bias would yield the same bias towards the mean size, with two smallest circles overestimated and two largest circles underestimated. In the incongruent-bias condition, however, two smallest circles were surrounded by bigger circles and two largest circles were surrounded by smaller circles, such that perceptual illusion would yield bias away from the mean, unlike the VWM encoding bias towards the mean. For baseline, we also created two control conditions containing randomly intermixed inducers and no inducers at all. Although we observed the strong bias towards the mean in all the conditions, we found the significant difference between the congruent and incongruent bias conditions: the congruent condition amplified the overall bias to the mean, while the incongruent condition attenuated it. This corresponds to a perceptual bias predicted by the direction of the Ebbinghaus illusion in both conditions, indicating the additive interaction between perceptual size illusion and VWM encoding bias on recall, with the stronger effect of VWM encoding bias.

26.4103 Making a categorical decision does not modify the stimulus representation in working memory Long Luu[1](longluu@sas.upenn.edu), Alan Stocker[1]; [1]Department of Psychology, University of Pennsylvania

Making a categorical decision about a stimulus can bias an observer's subsequent percept of the stimulus' parameters. We have previously demonstrated that these biases arise because human subjects seem to condition their percepts on their preceding decisions such that they maintain consistency across a sequential assessment of the same stimulus (Luu & Stocker VSS 2015). What remains unclear is how the conditioning is implemented. One possibility is that a decision directly modifies the stimulus representation in working memory such that the information that is inconsistent with the decision outcome is erased (implicit conditioning). Alternatively, the stimulus representation remains intact while the decision outcome is stored and used as an additional bit of information in the inference process downstream (explicit conditioning). We experimentally tested the two alternatives by probing how an incorrect categorical decision affects an observer's ability to reconstruct the stimulus parameter. Similar to our previous study, we briefly presented subjects with an array of small line segments whose orientations were sampled from a Gaussian centered

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around the true stimulus orientation. Subjects first had to report whether the overall array orientation was clockwise/counterclockwise relative to a reference orientation. After receiving feedback about their decision, they were asked to reconstruct the stimulus orientation by adjusting a pointer. Consistent across all five tested subjects, we found that in trials where subjects made an incorrect categorical decision their estimation biases depend on stimulus uncertainty. Implicit conditioning is not in agreement with this behavior. Because it assumes that the relevant stimulus information has been erased, it predicts that subjects' estimates are left to chance and thus are insensitive to stimulus uncertainty. In contrast, an observer model assuming explicit conditioning closely predicts the measured biases, suggesting that a categorical decision does not alter the stimulus representation in working memory in a sequential inference task.

26.4104 **Hungry, hungry singletons: Unique items eat up visual working memory resources** Jason Rajsic[1](jason.rajsic@mail.utoronto.ca), Sol Sun[1], Lauren Huxtable[1], Susanne Ferber[1,2], Jay Pratt[1]; [1]Department of Psychology, University of Toronto, [2]Rotman Research Institute, Baycrest

Objects that differ from their neighboring objects in terms of a salient visual feature – referred to as feature singletons – are known to capture attention under a wide range of conditions. However, little is known about whether their salience affects encoding of information into visual working memory (VWM). In the present experiment, we asked participants to remember the orientations of four colored triangles over a brief delay. On half of the trials, one triangle possessed a unique color, and on another half, all triangles had the same color. Although color was truly task-irrelevant (all triangles were equally likely to be tested), the probability of an item being remembered was higher when its color was unique. Furthermore, individual differences in VWM performance on non-singleton trials predicted the difference in memory between singleton and non-singleton items on trials where a singleton was present. Our results highlight the contribution of physical salience to the information that is encoded in visual working memory

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

26.4105 **Electrophysiology reveals different mechanisms of attentional filtering during visual working memory encoding and retention** Hiroyuki Tsubomi[1](htsubomi@hmt.u-toyama.ac.jp), Keisuke Fukuda[2], Atsushi Kikumoto[3], Edward Vogel[4]; [1]University of Toyama, [2]Vanderbilt University, [3]University of Oregon, [4]University of Chicago

The severe capacity limit of visual working memory (VWM) necessitates an efficient filtering mechanism to represent task-relevant items in VWM and restrict task irrelevant items from consuming capacity. Previous studies have shown that selective attention benefits post-perceptual as well as perceptual processing by filtering unnecessary items out of VWM (Vogel, McCollough, & Machizawa, 2005). The present study asked whether the attentional filtering is supported by the same mechanism across various loci of VWM processing such as encoding and retention stages. To answer this question, we measured the contralateral delay activity (CDA), a neural index of VWM capacity, while participants filtered out task-irrelevant VWM representations. Participants were asked to remember four sample color squares to be tested after a 1s delay period. In the selective encoding condition, a position-cue was presented at one of the four color squares at the sample display. The position-cue indicated a test location, allowing the participants to selectively encode only the cued item in VWM. In the selective forgetting condition, the same position-cue was presented at the middle of the delay period, allowing the participants to selectively hold the cued item in VWM and to forget the other three color squares. Behavioral results showed both cues improved the performance compared to the baseline condition in which the position-cue was not presented. However, the CDA showed sizable reduction only in the selective encoding condition, but not in the selective forgetting condition. These results suggest that although an attentional cue benefits the behavioral performance at both the encoding and retention stage in VWM, underlying mechanism for these cueing benefits are dissociable. Namely, while the attentional selection at the encoding stage are coupled with excluding unnecessary items from VWM, attentional selection at the retention stage does not accompany exclusion of no-longer necessary items from VWM.

26.4106 **The pupillary light response reflects encoding, but not maintenance, in visual working memory** Stefan Van der Stigchel[1](s.vanderstigchel@uu.nl), Tessel Blom[1], Christiaan Olivers[2], Sebastiaan Mathot[3]; [1]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, [2]Department of Cognitive Psychology, Vrije Universiteit Amsterdam, [3]Aix-Marseille University, CNRS, LPC UMR 7290

Traditionally, the pupillary light response (PLR) has been thought to reflect the amount of light entering the eye. However, recent studies have shown that the PLR is not just a reflexive process, but is also affected by cognitive factors, such as covert visual attention. Given that the PLR appears sensitive to higher order perceptual representations, we examined whether the pupillary light response is modulated by stimuli which are not physically present, but maintained in visual working memory. In all conditions, displays contained both bright and dark stimuli. Participants were instructed to covertly attend and encode either the bright or the dark stimuli, which then had to be maintained in visual working memory for a subsequent change-detection task. As expected, the pupil was smaller when the bright stimuli had to be encoded compared to when the dark stimuli had to be encoded. This indicates that the encoding of information into visual working memory is reflected in the PLR. However, this effect did not sustain during the maintenance phase. This was consistent across all three experiments: whether it was the shape (Experiment 1), orientation (Experiment 2), or luminance (Experiment 3) of the stimulus that was relevant for subsequent behaviour, the maintenance of the stimuli was not reflected in the PLR. A subsequent Bayesian analysis showed that pupil size was likely driven by the brightness of stimuli during encoding, but not maintenance, of visual working memory. We conclude that the content of visual working memory is not reflected in the pupil. Since the pupil has been linked to the focus of visual attention, the results also suggest that attention is not necessary for the maintenance of information in visual working memory.

26.4107 **Inhibition of Return in Visual Working Memory** Benchi Wang[1](wangbenchi.swift@gmail.com), Chuyao Yan[2], Zhiguo Wang[2,3], Jan Theeuwes[1], Christian Olivers[1]; [1]Department of Cognitive Psychology, Vrije Universiteit, Amsterdam., [2]Department of Psychology, Hangzhou Normal University., [3]Department of Cognitive Science, Macquarie University.

Previous studies have shown that visual working memory (VWM) representations can be strengthened by pre-cues presented prior to the memory display, as well as retro-cues presented after the memory display, providing evidence for attentional orienting playing a role in memory encoding and maintenance. However, it is known from attentional orienting studies that cueing can lead to a biphasic effect, where facilitation is followed by inhibition – a phenomenon known as inhibition of return. Here we explored whether pre- and retro-cues lead to inhibition of return within VWM. In Experiment 1, a cue was shown before a sample display consisting of various colors, with SOAs of 200 ms and 400 ms. After a 1000 ms delay, one of the colors was tested using a continuous color wheel. Experiment 1 showed that the pre-cue increased the probability of an item being encoded in VWM at the short SOA, whereas probability was reduced for the long SOA. In Experiment 2, a retro-cue was used, presented 200 ms after sample display offset. Crucially, after 350-450 ms, attention was then cued back to the center of the display or left to linger on the cued item. The results showed that the retro-cue improved the probability of remembering. Importantly, when attention was cued back to the center, the precision of the cued item deteriorated. In summary, we conclude that VWM representation not only can be facilitated, but also inhibited by pre- and retro-cues.

Acknowledgement: ERC Consolidator grant 615423 to CNLO and ERC advanced grant [ERC-2012-AdG-323413] to Jan Theeuwes

26.4108 **Search for targets in visual working memory is biased by statistical learning** Bo-Yeong Won[1](won.93@osu.edu), Andrew Leber[1]; [1]Department of Psychology, The Ohio State University

Much recent research has demonstrated how statistical learning biases spatial attention toward targets in the external environment. However, attention can also be directed to internal representations; does statistical learning guide attention within working memory representations? To address this, we had participants encode four items in working memory and then search for one "target" item within the encoded representation. To promote statistical learning, the target appeared more frequently in one quadrant (i.e., rich quadrant) than the other three quadrants (i.e., sparse quadrants). Results showed participants were faster and more accurate to locate targets in the rich compared to sparse quadrants. This suggests that participants learned to prioritize their working memory search toward the rich quadrant. However, an alternative explanation is that participants learned to selectively memorize the item in the rich location during the encoding stage. To rule out this "encoding bias" possibility, we modified the task to include multi-feature items. Specifically, participants had to remember the color and shape for each of the four items. Then, one feature target, either a colored circle or a white shape, appeared in the center. Participants reported the feature's location in the memory display. Unbeknownst to participants, color targets were more frequently located in one "color-rich" quadrant, while shape targets were more frequently located in another "shape-rich" quadrant. Results showed that performance was faster and more accurate for color – but not shape – targets when they appeared in the color-rich quadrant; we found the same pattern for shape – but not color – targets when they appeared in the shape-rich quadrant. These results show that observers encoded each multi-feature object equally but biased their memory search depending on the statistics associated with each feature. We thus confirm that statistical learning can guide search within working memory representations.

26.4109 **Effects of Familiarity on Visual Short-Term Memory for Pokémon** Weizhen Xie[1](weizhen.xie@email.ucr.edu), Weiwei Zhang[1]; [1]Department of Psychology, University of California, Riverside

Long-Term Memory (LTM) can influence Short-Term Memory (STM) storage capacity in the verbal domain (e.g., increased verbal STM span for high-frequency words). In contrast, it is under debate whether similar effects manifest in the visual domain. That is, can we retain more representations in visual STM for stimuli that we are more familiar with? The current study addressed this question by taking advantage of participants' prior rich multimedia experience with Pokémon, without investing on laboratory training. In a Pokémon STM change detection task (Experiment 1), one group of participants remembered more familiar first-generation Pokémon characters than unfamiliar recent-generation Pokémon stimuli. No significant difference in memory quality was found when quantitative and qualitative effects of LTM were isolated using receiver operating characteristic curves. Critically, these effects were absent in another group of participants who were unfamiliar with the first generation Pokémon. Furthermore, several alternative interpretations were ruled out, including Pokémon preference, verbal encoding, and general video gaming experience. Experiment 2 examined whether this quantitative boost resulted from faster consolidation speed using limited encoding time with consolidation masking. The results suggested that STM consolidation was faster for familiar first-generation Pokémon, which consequently led to increased capacity, relative to less familiar recent-generation Pokémon. Again this effect was absent in participants who were not familiar with the first-generation Pokémon. Experiment 3 extended memory array duration to 1 second so that STM consolidation was no longer a limiting factor on overall performance. No significant effect of familiarity on STM capacity was found. Together, the present study provided strong evidence supporting facilitations of visual STM by existing visual LTM. Specifically, visual LTM speeds up visual STM consolidation, which could manifest as increased STM storage capacity when encoding time is limited. These results provide some insights into evaluating theories on relationships between STM and LTM.

26.4110 **When you know it was there - you remember how it looked: effects of semantic context on memory for 'gist' and for visual details.** Nurit Gronau[1](nuritgro@openu.ac.il), Anna Izoutcheev[1], Inbal Ravreby[1], Elia Barkai[1]; [1]Department of Psychology, The Open University of Israel.

How vivid is our memory following a very brief glance? Visual information tends to fade over time, such that only salient objects and events within a scene are retained in long-term memory. Schematic knowledge may aid in the encoding and retrieval of specific items, yet there is an unresolved dispute concerning the nature of this effect – are contextually consistent, or inconsistent stimuli mostly enhanced and remembered? Furthermore, relatively little is known about the contribution of associative information to recognition of the precise visual appearance of objects. Since schematic knowledge is typically thought to be abstracted from instances or episodic detail, information about perceptual details may be orthogonal and irrelevant to the schema. Here we investigated the effects of contextual consistency factors on memory for categorical (i.e., item type) as well as for visual detail (token) information of merely glimpsed objects. Participants viewed pairs of contextually related and unrelated stimuli. They then performed a forced-choice memory recognition task that tested for both category and visual detail knowledge. Results showed that categorical memory (e.g., recognizing an old pair of scissors) was overall enhanced for stimuli appearing within contextually consistent, relative to contextually inconsistent pairs. Interestingly, this effect was largely explained by the specific visual appearance of the items (e.g., recognizing the red pair of scissors) within the contextually consistent pairs. We propose that that during a brief glimpse, contextual associations play an important role in reducing stimulus competition and in facilitating rapid encoding of an item's 'gist' as well as its sensory details. We will discuss our findings with respect U-function models of memory, according to which both highly novel (schema-inconsistent) and highly expected (schema-consistent) information benefit from increased memory representation.

Acknowledgement: This research was funded by the Israel Science Foundation.

Saturday PM

Eye Movements: Saccades and pursuit

Sunday, May 15, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Miriam Spering

31.11, *8:15 am* **When hand movements improve eye movement performance** Jolande Fooken[1,2](jolande.fooken@rwth-aachen.de), Kathryn Lalonde[1,2], Miriam Spering[1,3,4,5]; [1]Ophthalmology & Visual Sciences, UBC, [2]Graduate Program in Neuroscience, UBC, [3]Institute for Computing, Information and Cognitive Systems, UBC, [4]Centre for Brain Health, UBC, [5]International Collaboration on Repair Discoveries, UBC

Tracking a moving object with smooth pursuit eye movements enhances our ability to predict an object's trajectory. Here we assessed the relationship between pursuit and hand movements and compared the efficacy of different training protocols on eye and hand movement accuracy. In a novel track-intercept task observers tracked a target moving across a screen and hit it with their index finger after it entered a "hit zone". Following brief presentation (100-300 ms), observers had to extrapolate and intercept the target at its assumed position; feedback about actual position was given after interception. We conducted three experiments with different training protocols. In each experiment, baseline pursuit (fully visible trajectory) and track-intercept task were tested on day 1 (pre-test) and day 5 (post-test). During training (days 2-4), observers either: tracked and intercepted the target (n=9, eye-hand-training), tracked but did not intercept (n=9, eye-training), or received no training (n=9). We analysed effects of training type and day on the accuracy of eye and hand movements. Manual interception accuracy improved significantly across groups, but effects were larger for the training groups than after no training. By contrast, improvements in eye movements were only observed after training and not in the control group. Interestingly, despite equal exposure to the tracking task during training, smooth pursuit was more accurate after combined eye-hand training vs. eye training. These benefits (significantly higher peak eye velocity, gain, lower position error, shorter latency) were observed in the track-intercept task and in baseline pursuit on day 5, indicating global pursuit performance improvements after eye-hand training. Eye-movement training improves the accuracy of hand movements, and engaging the hand during eye-movement training, in return, enhances smooth pursuit. These findings support the idea of shared pathways for eye-hand movement control and have implications for our understanding of transfer in perceptual-motor learning tasks.

Acknowledgement: NSERC DG and CFI John R. Evans Leaders Fund to MS

31.12, *8:30 am* **A tight coupling between finger and oculomotor commands** Jing Chen[1](Jing.Chen@psychol.uni-giessen.de), Matteo Valsecchi[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

When human observers track the movements of their own hand with gaze, the eyes can start moving before the finger (i.e., anticipatory smooth pursuit). This anticipation could be the result of a strict coupling between finger and eye motor programming or simply result from a higher-level decision-based predictive signal associated with self-initiated movements. For the present study, we built a mechanic device which could move a visual target either in the same direction of the subjects' hand or towards the opposite direction in different blocks. Observers (N = 12) moved their finger, which was not visible, to either the left or right and back, and were asked to track the visual target with their gaze. The movement length before turning back was on average 19.2 deg (i.e., 10.1 cm; ranging from 15.5 to 22.8 deg). The speed of the finger movement was 26.8 deg/s on average (ranging from 19.6 to 36.6). Congruent pursuit showed stronger anticipation compared to opposite pursuit, as evidenced by decreased pursuit latency (-55 vs -34 ms, respectively), increased lead of the eye to target in positions (0.64 vs 0.41 deg, in the [0 400] ms window after finger onset), decreased saccade rate (0.60 vs 0.71 per second, in the [0 400] ms window), and decreased delay at reversal (10 vs 18 ms). Although some degree of anticipation is occurring for incongruent pursuit, indicating that there is a role for higher-level movement prediction in pursuit anticipation, the fact that anticipation is improved when target and finger move towards the same direction suggests that there is also a direct coupling between finger and eye motor commands.

Acknowledgement: the DFG International Research Training Group, IRTG 1901,

31.13, *8:45 am* **Target color and shape can control contextual saccadic adaptation** Sohir Rahmouni[1](sohir.rahmouni@gmail.com), Jéremie Jozefowiez[1], Laurent Madelain[1]; [1]Univ. Lille, CNRS, CHRU Lille, UMR 9193 - SCALab - Sciences Cognitives et Sciences Affectives, F-59000 Lille, France

Saccade adaptation is a form of motor learning that maintains saccade accuracy when facing new sensorimotor contingencies. Researchers have shown that distinct saccade gain states can be adapted simultaneously in a double-step paradigm depending on contexts acting on the motor command (e.g. velocity or direction of target motion, head tilt, orbital eccentricity, or vergence). However, purely visual cues such as target color or shape consistently failed to drive different gain states during saccadic adaptation. Since Deubel's work in 1995, this question has remained unsolved despite extensive research in both human and non-human participants. The present work investigates whether this lack of contextual control might be due to a lack of relevance of the contextual cue to the saccadic system. We modified the conventional intrasaccadic step paradigm by displaying a distractor at the back-stepped location when the target stepped forward and vice-versa. In a first experiment the pre-saccadic target color (red or green) indicated its intra-saccadic step (backward or forward) and a distractor (green or red) was displayed after the saccade landed (at the forward-stepped or back-stepped location). We observed contextual control of saccade adaptation, which did not occur when the distractor was not displayed. In two other experiments we found the same effect using shape or shape and color as contextual features. We conclude that feature-based selection of the target promotes contextual adaptation. Three additional experiments further confirmed that i) when two features of the context cues are conflicting, contextual adaptation is blocked, ii) the spatial reference provided by the distractor is not responsible for our contextual adaptation and iii) removing the distractor during the adaptation phase induces a progressive decrease in adaptation. These results indicate that any context could potentially control contextual saccadic adaptation provided that the relation between the context cue and the saccadic response is made relevant.

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31.14, *9:00 am* **Prior knowledge of the locations of potentially relevant objects reduces effects of visual salience** Mieke Donk[1](w.donk@vu.nl), Jeroen Silvis[1], Jan Theeuwes[1]; [1]Department of Cognitive Psychology, Vrije Universiteit Amsterdam

The aim of the present study was to investigate whether the effects of visual salience on early oculomotor selection can be modulated by prior knowledge regarding the identities and locations of potential saccadic targets. In two experiments, participants were asked to make a saccade to a singleton target line (e.g. left tilted) that was presented with a singleton distractor line (tilted in the opposite direction) in a homogenous field of background lines. The salience of the target was either high or low relative to the salience of the distractor. The Stimulus Onset Asynchrony (SOA) between the singletons and the background elements was manipulated in order to dissociate the availability of information concerning the identities of the singletons, the locations of the singletons, and the salience of the singletons. The singletons were either presented simultaneously with the background lines (Experiment 1 and 2), prior to the background lines (Experiment 1 and 2), or after the background lines (Experiment 2). The results indicate that when the singletons and background lines were presented asynchronously, the salience of the target relative to the distractor had a reduced effect on selection performance. This decrease in the effect of salience occurred regardless of whether the singletons were presented before or after the appearance of the background lines. The results suggest that the availability of information concerning the locations of potentially relevant objects makes oculomotor behavior less sensitive to relative differences in salience among those objects.

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31.15, *9:15 am* **Spatiotopic integration facilitates post-saccadic perception.** Jasper Fabius[1](j.h.fabius@uu.nl), Alessio Fracasso[1,2], Stefan Van der Stigchel[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, [2]Radiology, Rudolf Magnus Institute of Neuroscience, University Medical Center Utrecht

Sunday AM

Saccades rapidly reposition the most sensitive portion of the retina, the fovea, to interesting locations. However, they represent a challenge for the construction of a spatiotopic visual representation over time. It is currently unclear whether visual information is accumulated across eye movements or starts anew after each separate fixation. We investigated this issue using a visual motion illusion ("high phi"; Wexler et al. 2013) in which a random texture (inducer), slowly rotating clockwise or counter-clockwise, is replaced with a rapid succession of different textures (transient). With sufficiently long inducer durations, participants report the transient as a large rotational jump in the direction opposite to inducer direction (backward jumps). Crucially, the stability of the perceived jump depends on the inducer duration, eventually settling with consistent perceptions of backward jumps for longer inducer durations. This allowed us to compare the benefit of spatiotopic representations on the speed of perceptual processing. We measured the influence of inducer duration in the high phi illusion in different experimental conditions, varying the reference frame of the transient with respect to the inducer (spatiotopic or retinotopic). When the pre-saccadic inducer and the post-saccadic transient were presented in spatiotopic coordinates we observed a faster buildup of a bias in perceived jump direction, as compared to the same condition without eye movements. In control conditions we confirmed that the observed spatiotopic effect is not the result of a long-range effect, but it is tied to saccade execution. Together, these findings (I) provide strong evidence for the existence of spatiotopic storage of visual information, and (II) indicate that pre-saccadic visual input affects post-saccadic input by facilitating the spatiotopic interpretation of the visual information in the new fixation.

31.16, *9:30 am* **Oculomotor entraining and persistent baseline drift in saccadic adaptation to a sinusoidal disturbance** Carlos Cassanello[1,2](carlos.cassanello@bccn-berlin.de), Florian Ostendorf[3], Martin Rolfs[1,2]; [1]Bernstein Center for Computational Neuroscience Berlin, Germany, [2]Department of Psychology, Humboldt University Berlin, Germany, [3]Charité, Berlin, Germany

We assessed the dynamics of changes in the metrics of saccades in response to time-varying disturbances of visual feedback. Observers made naturally paced saccades in adapting blocks of 600 target steps with fixed amplitude of 8 degrees either in horizontal or unconstrained directions. During each saccade, the intra-saccadic shift (ISS)—following a sinusoidal variation as a function of the trial number—displaced the target along its vector by -25% (inward) to +25% (outward) of the presaccadic target eccentricity. Formal comparison of a range of descriptive models fitted to the oculomotor response averaged across participants revealed two clearly distinct additive components: (1) a sinusoidal variation with the same frequency, lagging the ISS by about 20 trials and scaled down in amplitude, and (2) a persistent drift in the baseline, systematically increasing hypometria despite the absence of a consistent negative visual error. We captured these dynamics using a generative model consisting of a simple state equation that predicts the size of the upcoming saccade with two contributions: a learning term in which a feedback coefficient (k) weights the visual error experienced on the previous trial, and a persistence term in which a 'retention' coefficient (c) defines what portion of the predicted size of the last executed movement is retained in the next. In this framework, the sinusoidal response, while resulting from a trial-by-trial error correction process well described in the literature on sensorimotor learning, may inform how the retention and feedback coefficients get tuned to match or mitigate the stimulus features. The drift would then be an outcome of this process that does not determine nor hamper the learning of the stimulus. Following these ideas, we discuss additional effects of a reduced retention coefficient. Our results show how periodic disturbances in the experienced saccadic error, provides new insights into learning in the oculomotor system.

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Face Perception: Neural mechanisms

Sunday, May 15, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Kendrick Kay

31.21, *8:15 am* **Hemispheric Organization in Congenital Prosopagnosia: The N170 in Words and Faces** Elliot Collins[1,2,3], Eva Dundas[1,2], Marlene Behrmann[1,2]; [1]Department of Psychology, Carnegie Mellon University, [2]Center for the Neural Basis of Cognition, [3]School of Medicine, University of Pittsburgh

A recent theoretical account (Behrmann & Plaut, 2011, 2015) and associated empirical data (Dundas et al., 2013) argues for the interdependence of the development of hemispheric organization for words with that of faces in typically developing children. Specifically, the claim is that, during the course of acquiring word recognition skills, the pressure to couple visual and language representations in the left hemisphere (LH) results in competition for representation of faces, and these latter representations become largely lateralized in the right hemisphere (RH). This account makes a specific prediction with regard to atypical development and that is that typical hemispheric organization for words can develop in the context of atypical development of face processing but not vice versa, and the latter prediction is upheld in recent findings from individuals with developmental dyslexia. We explore the first prediction using a visual hemifield presentation paradigm with words and faces, with concurrent ERP measurement, in a group of adults with congenital prosopagnosia (CP), a lifelong impairment in face recognition, and typically developed controls. In contrast with the controls, the CP group failed to produce the dominant RH response for faces, with equal magnitude N170 components elicited by faces and words. Both the controls and the CP adults, however, produced a dominant LH response for words, with greater N170 component in response to words than to faces. Differences between the groups in hemispheric organization were specific to the N170 and were not found in the P100 component. These findings are consistent with the account that typical hemispheric organization for words can develop in the absence of typical hemispheric organization for faces. Additionally, when considered with evidence from developmental dyslexia, the results here support the directionality of interdependent hemispheric development and the hypothesis that hemispheric organization for words may precede that for faces.

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31.22, *8:30 am* **Network-level interactions drive response properties in word- and face-selective cortex** Jason Yeatman[1](jyeatman@uw.edu), Kendrick Kay[2]; [1]Institute for Learning & Brain Science and Department of Speech & Hearing Science, University of Washington, [2]Department of Radiology, University of Minnesota

High-level perceptual functions depend on complex interactions within networks of brain regions. However, the typical approach in high-level vision is to localize brain regions that respond selectively to particular categories of images and to probe response properties focusing on these specific regions. Here we show that to understand the computations performed by high-level visual regions, it is essential to analyze the connectivity of the region and model responses in the context of the larger network in which the region resides. We used fMRI to localize word-selective (VWFA-1, VWFA-2) and face-selective (FFA-1, FFA-2) regions in ventral temporal cortex (VTC). We then measured responses in these regions to a wide range of carefully controlled grayscale images while subjects performed different tasks that isolate bottom-up, stimulus-driven responses from top-down, task-dependent modulations. Our measurements demonstrate that VTC is not only sensitive to stimulus properties (e.g. image category) but is also substantially affected by the task performed on the image. Importantly, we find that the observed task sensitivity is predictable based on the pattern of white-matter connections between each region and the rest of the brain. VWFA-1 and FFA-1 are directly connected with the intraparietal sulcus (IPS) through the vertical occipital fasciculus (VOF), and we find that task-related response modulation in VWFA-1 and FFA-1 can be predicted with a model that incorporates the evoked response in IPS to each stimulus. In contrast, VWFA-2 is directly connected with Broca's area through the arcuate fasciculus, and we find that this connection imparts substantial word selectivity when subjects perform tasks involving linguistic analysis of visually presented words. These results show that anatomical connections between VTC and parietal and frontal cortex support functional interactions that fundamentally shape response properties in VTC.

31.23, *8:45 am* **A Neural Basis of Facial Action Recognition in Humans** Ramprakash Srinivasan[1](srinivasan.134@osu.edu), Julie Golomb[2], Aleix Martinez[1]; [1]Electrical and Computer Engineering, The Ohio State University, [2]Department of Psychology, The Ohio State University

By combining different facial muscle actions, called action units, humans can produce an extraordinarily large number of facial expressions. Computational models and studies in cognitive science and social psychology have long hypothesized the brain needs to visually interpret these action units to understand other people's actions. Surprisingly, no studies have identified the neural basis of the visual recognition of these action units. Here, using functional Magnetic Resonance Imaging and an innovative machine learning analysis approach, we identify a consistent and differential coding of action units in the brain. Crucially, in a brain region thought to be responsible for the processing of changeable aspects of the face, multi-voxel pattern analysis could decode the presence of specific action units in an image. This coding was found to be consistent across people, facilitating the estimation of the perceived action units on participants not used to train the multivoxel decoder. Furthermore, this coding of action units was identified when participants attended to the emotion category of the facial expression, suggesting an interaction between the visual analysis of action units and emotion categorization as predicted by the computational models mentioned above. These results provide the first evidence for a representation of action units in the brain and suggest a mechanism for the analysis of large numbers of facial actions and a loss of this capacity in psychopathologies.

Acknowledgement: National Institutes of Health Grants R01-EY-020834 and Alfred P. Sloan Foundation grant BR-2014-098.

31.24, *9:00 am* **Macromolecular proliferation in human high-level visual cortex constrains development of function and behavior** Jesse Gomez[1](gomezj@stanford.edu), Michael Barnett[2], Vaidehi Natu[2], Aviv Mezer[3], Kevin Weiner[2], Katrin Amunts[4,6,7], Karl Zilles[4,5,7], Kalanit Grill-Spector[1,2,8]; [1]Neurosciences Program, Stanford University School of Medicine, [2]Psychology Department, Stanford University, [3]Center for Brain Sciences, Hebrew University of Jerusalem, [4]Institute of Neurosciences and Medicine, Research Center Julich Germany, [5]Department of Psychiatry, Psychotherapy, and Psychosomatics, RWTH Aachen University, [6]C. and O. Vogt Institute for Brain Research, Heinrich-Heine University Dusseldorf, [7]JARA-BRAIN Julich-Aachen Research Alliance, Julich Germany, [8]Stanford Neurosciences Institute, Stanford University

Computations performed by a given cortical region are a product of its underlying cytoarchitecture and likely sculpted through development. Novel quantitative magnetic resonance imaging (qMRI) methods sensitive to such cortical properties (e.g. macromolecular tissue volume “MTV”, and tissue composition measured through T1 relaxation time “T1r”) allow us to explore the developmental interplay between neural structure, function, and behavior. Its anatomical consistency and prolonged development make human ventral temporal cortex (VTC) an ideal test bed to establish a fundamental and novel relationship within the nervous system: how anatomical changes in gray matter tissue relate to changes in function and ultimately behavior across development. Combining functional and quantitative MRI with behavior, we investigated if the development of a region’s functional selectivity, and subjects’ visual recognition ability, are constrained by changes in the underlying gray matter of VTC. From childhood (n=22, 5-12yo) to adulthood (n=25, 22-28yo), we find face-selective cortex is characterized by decreasing T1r (increased MTV; Figure 1A) with correlated increases in functional selectivity (Figure 1B). In place-selective cortex, T1r and consequently selectivity do not develop. We demonstrate that recognition memory is correlated across development with tissue properties in face-selective cortex, with lower T1r (higher MTV) associated with improved recognition ability for faces, but not places (Figure 1B). In addition, we relate quantitative differences in macromolecular tissue properties between face- and place-selective cortex to ex vivo histology employing a novel ex-to-in vivo registration pipeline. We demonstrate that post mortem descriptions of cellular organization in two new cytoarchitectonic regions in VTC mirror our in vivo measurements (Figure 1C). Lastly, while such cytoarchitectonic differences are measurable in our living adults, such differences have yet to emerge in childhood. Together, these data offer a novel behaviorally relevant model by which emergent functional properties shape, or are shaped by, structural development in human visual cortex.

31.25, *9:15 am* **Facial image reconstruction: a multimodal neuroimaging and behavioral investigation** Adrian Nestor[1](anestor@utsc.utoronto.ca), Dan Nemrodov[1], David Plaut[2,3], Marlene Behrmann[2,3]; [1]Department of Psychology at Scarborough, University of Toronto, [2]Department of Psychology, Carnegie Mellon University, [3]Center for the Neural Basis of Cognition

Recent work on neural-based image reconstruction has established the ability of fMRI patterns to support this enterprise. However, these attempts rely on prespecified image features motivated by their general biological plausibility. Here, we take on the task of deriving facial image-based features directly from patterns of empirical data and of using those features for the purpose of face reconstruction. Also, we exploit the current approach and confirm its robustness by its separate application to fMRI, EEG and psychophysical data. More specifically, we collect behavioral and neuroimaging data in healthy adults during individual face recognition (e.g., during a one-back identity task). These data are subjected to a method akin to reverse correlation able to derive facial features separately from behavioral and neural responses by exploiting confusability patterns associated with different facial identities. Then, we combine those features to reconstruct novel face images based on the responses that they elicit. This approach allows us: (i) to estimate an entire gallery of visual features associated with different neural signals, (ii) to support significant levels of reconstruction accuracy for any of the empirical modalities considered (i.e., fMRI, EEG and psychophysical data), and (iii) to relate homologous representations derived from different modalities. From a theoretical perspective, the present findings provide key insights into the nature of high-level visual representations, into their reliance upon specific neural resources (e.g., different cortical areas) and into joint brain-behavior models of face processing. At the same time, they make possible a broad range of image-reconstruction applications via a general, multimodal methodological approach.

31.26, *9:30 am* **Beyond the core face-processing network: intracerebral stimulation of a face-selective area in the right anterior fusiform gyrus elicits transient prosopagnosia** Jacques Jonas[1,2](jac.jonas@gmail.com), Bruno Rossion[1]; [1]University of Louvain, Belgium, [2]University Hospital of Nancy, France

According to neuropsychological evidence, a distributed network of face-selective regions of the ventral visual pathway supports face recognition. However, fMRI studies have generally confined to the posterior face-selective areas, i.e., the occipital face area (OFA) and the fusiform face area (FFA). There is recent evidence that intracranial electrical stimulation of the OFA and FFA elicits face recognition impairments. Here we were able to test for face recognition in a patient implanted with depth electrodes in the anterior temporal cortex. Electrically stimulating the right anterior fusiform gyrus, in a region located anteriorly to the FFA, induced a transient inability to recognize familiar faces (see Figure 1 in additional information; movies available). This region was shown face-selective as revealed by intracerebral face-selective event-related potentials and gamma band activity recorded at these critical electrodes. However, no fMRI face-selective responses were found in this region due to severe BOLD signal drop-out caused by the ear canal artifacts (see Figure 2 in additional information). These results point to a causal role in face recognition of the right anterior fusiform gyrus and more generally of face-selective areas located beyond the “core” face processing network in the anterior ventral temporal cortex. It also illustrates the diagnostic value of intracerebral recordings and stimulation in understanding the neural basis of face recognition and visual recognition in general.

Color and Light: Neural mechanisms

Sunday, May 15, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Michael Rudd

32.11, *10:45 am* **Brightness in human rod vision depends on neural adaptation to the quantum statistics of light** Michael Rudd[1,2](m-rudd@uw.edu), Fred Rieke[1,2]; [1]Howard Hughes Medical Insitute, [2]Department of Physiology and Biophysics, University of Washington

In cone-mediated vision, light adaptation obeys Weber’s law (constant visual response to constant contrast). Weber adaptation begins in the cones themselves and is well suited to support color constancy. In rod-mediated vision, the visual input consists of a retinal rain of discrete photons. Individual rods do not receive a sufficient number of light quanta within their integration time to light adapt. Instead, light adaptation occurs in post-receptoral circuitry. The nature of this adaptation is still poorly understood. Since the pioneering work of Barlow (1956, 1958), it has been known that psychophysical rod thresholds, when measured with small, brief test probes, increase in proportion to the square-root of adapting intensity, rather than in direct proportion to intensity (Weber’s law). A bedrock idea of classical psychophysics ascribes the square-root law to the masking of dim threshold flashes by the naturally occurring variability in the photon rain from the adapting field (Shapley & Enroth-Cugell, 1975). Importantly, this classical explanation does not require actual physiological adaptation and, classically, none was assumed. Here, we present the results of three brightness matching experiments that together demonstrate that the square-root law arises from a neural adaptation (monocular gain control), driven by statistical photon inputs, that influences brightness as well as threshold. The experiments were performed in a haploscope with one eye’s adaptive state manipulated and the other eye used as a reference. Our results show that: 1) brightness gain for supra-threshold flashes varies inversely with the standard deviation of the quantal fluctuations from the adapting field; 2) brightness gain is controlled by both the mean and variance of time-integrated photon inputs and changes only slowly (adaptation takes a few minutes). These properties suggest that brightness at low light levels evolved to encode the reliability (signal-to-noise ratio) of sparse statistical light inputs, rather than either luminance or contrast.

Acknowledgement: Howard Hughes Medical Institute

32.12, *11:00 am* **Light adaptation and the human temporal response revisited** Andrew Rider[1](a.rider@ucl.ac.uk), Bruce Henning[1], Andrew Stockman[1]; [1]Institute of Ophthalmology, UCL

Light adaptation speeds up visual processing such that observers become relatively more sensitive to high-frequency flicker. Adaptation changes the temporal contrast sensitivity functions (TCSFs) from low-pass to band-pass: at low temporal frequencies contrast sensitivity remains approximately constant (Weber's Law), whereas at the highest frequencies it depends on flicker amplitude and therefore increases (high-frequency linearity). Several distinct models have been proposed to account for these complexities. Here, we re-evaluate them by modelling across existing TCSF data. Models that account for TCSF data are usually built up from low- and high-pass filters and typically differ in (i) the form and physical explanation of the filters, and (ii) which filters light adapt. Importantly, these models predict significant differences in how thresholds decline with frequency. One type of model predicts thresholds fall exponentially with frequency (consistent with the Ferry-Porter law); a second, based on solutions to diffusion equations, predicts that it falls with the square root of frequency; and a third, based on cascaded integrators, predicts that it falls with the power of frequency (with a slope equal to the number of integrators). Existing TCSF data vary significantly due to differing stimulus parameters and perhaps individual differences, but are most consistent with a Ferry-Porter-like asymptote. We demonstrate that a model based on cascaded integrators and appropriate feedback can produce an approximately exponential fall-off in threshold over a broad frequency range (15-60 Hz) tending toward a power law asymptote at frequencies that are too high to be visually insignificant (>100Hz). Our model contains two intensity-dependent terms, one controls the time constant of the low-pass filters and the other controls the overall gain to account for bleaching effects. The model also accounts for several other flicker perception phenomena including Weber's law at low frequencies, high-frequency linearity and the Ferry-Porter law in flicker fusion.

Acknowledgement: BBSRC

32.13, *11:15 am* **Contrast gain control before and after cataract surgery: a case study** Donald MacLeod[1](dmacleod@ucsd.edu), Stuart Anstis[1]; [1]Psychology, UC San Diego

Purpose: Cataracts may greatly reduce the contrast of the retinal image, but the visual consequences of this contrast loss could be mitigated by neural adaptation (provided that the contrast of the stimulus is sufficient for it to be visible at all). We sought evidence for such neural adaptation. Methods: We investigated the suprathreshold perception of contrast, as well as contrast sensitivity, in one observer (author SA). We measured the attenuation of perceived contrast using binocular matches of contrast to reference stimuli viewed by the fellow eye. In addition the contrast differences needed for discrimination at a range of baseline contrast levels were measured in each eye. Such data were collected in the days immediately following surgical cataract removal, starting immediately after the eye patch was removed, as well as pre-operatively. Results: Pre-operatively, suprathreshold stimuli viewed by the cataract eye were judged at least a factor of three higher in contrast than expected on the basis of contrast threshold, so that contrast matches between the two eyes were more accurate than expected on the basis of the threshold difference. This suprathreshold contrast boost persisted post-operatively, so that now gratings could look higher in contrast to the operated eye than to the fellow eye. Contrast discrimination thresholds conformed to Weber's Law, and were similar for the two eyes. Conclusions: The binocular contrast matches reveal a neural 'contrast constancy' process that was able to compensate partly for the optical loss of contrast introduced by the cataract, producing a close approach to accurate contrast matching preoperatively and an 'overshoot' of perceived contrast post-operatively.

Acknowledgement: NIH EY01711

32.14, *11:30 am* **Estimating human colour sensors from rankings** Maryam Darrodi[1](m.darrodi@uea.ac.uk), Andrew Rider[2], Graham Finlayson[1], Andrew Stockman[2]; [1]School of Computing Sciences, University of East Anglia, [2]UCL Institute of Ophthalmology

Human colour perception depends initially on the responses of the long(L-), middle(M-) and short(S-) wavelength-sensitive cones. These signals are then transformed post-receptorally into cone-opponent (L-M and S-(L+M)) and colour-opponent (red/green and blue/yellow) signals and perhaps at some later stage into categorical colour signals. Here, we investigate the transformations from the cone spectral sensitivities to the hypothetical internal representations of 8 colour categories by applying a novel technique known as "Rank-Based Spectral Estimation". Pairs of colours were ranked by 12 observers according to which appeared more representative of eight different colour categories: red-green-blue-yellow-pink-purple-brown-orange. Stimuli comprised circular patches of 32 colours presented on a CRT monitor chosen to cover as large a volume of LMS colour space as possible. In separate blocks, observers judged pairs of colours as to which appeared more like the reference colour name. Pairs for which judgement could not be made, because neither colour appeared like the reference, were recorded but not used. To derive the spectral sensitivities of the colour categories (the 8 "colour sensors") using the rank-based technique, we assumed that the relationship between cone responses and colour appearance can be described by a linear transform followed by a rank-preserving non-linearity. The estimated sensor transformations could account for over 85% of the rank orders. Sensor shapes were generally plausible; those for red and green were consistent across observers, while the yellow and blue ones showed more variability in spectral position. Other sensors, such as brown, pink and purple, showed large inter-observer variability, which might be due in part to cultural differences in colour naming. Sensors were generally restricted to limited regions of colour space. As expected from colour opponent theory, the red and green sensors formed relatively distinct regions with limited overlap as did the yellow and blue ones. Other sensors were spectrally shifted or bimodal.

Acknowledgement: EPSRC BBSRC

32.15, *11:45 am* **Labeling the Lines: Asymmetric Color Matches Compared to a Six Mechanism Chromatic Detection Model** Timothy Shepard[1](timmyshepard@gmail.com), Safiya Lahlaf[1], Comfrey McCarthy[1], Rhea Eskew Jr.[1]; [1]Psychology, Northeastern University

Six linear chromatic mechanisms are sufficient to account for the pattern of threshold elevations produced by chromatic noise masking in the LM plane of cone space (Shepard et al, 2015). We assume the mechanisms are "labeled lines" (Graham 1989), implying here that the colors of physically-different stimuli that are detected by a single mechanism should all be the same, but that the colors of two stimuli detected by different mechanisms may differ. In the present study, three observers' detection thresholds, from multiple chromatic noise conditions, were fit with the six mechanism model. Observers were then presented the threshold-level tests (Gaussian blobs, σ=1°), in the presence of the same chromatic noises that were used in the detection experiment. Observers used a second display, positioned off to one side, to select a matching chromaticity on a HSV color wheel. According to the model, tests that lie along one mechanism threshold line should produce very similar color matches, while tests that lie on two different mechanism lines should be matched with appreciably different colors. In other words, the observers' color matches apply a label on each line, providing an additional test of the detection model and insight into the subjective experience resulting from these mechanisms. Cluster analysis shows that measured color matches fall into no more than 6 clusters in (u', v') space (across all the noise conditions), and these clusters correspond to the six mechanisms in the model. Furthermore, observed matches corroborate the qualitative differences between each observers' detection model fits. Most importantly, where the detection model determines that a given test angle is detected by different mechanisms in different noise conditions (due to differential masking), the hue of that test angle changes in a consistent way. These color matches verify the six-mechanism model, and quantify the hue signaled by each mechanism.

Acknowledgement: NSF BCS-1353338

32.16, *12:00 pm* **Non-linear Dynamics of Cortical Responses to Color in the cVEP** Robert Shapley[1](shapley@cns.nyu.edu), Valerie Nunez[2], Peter Schuette [2], Aneliya Hanineva[2], Afsana Amir[2], James Gordon[2]; [1]Center for Neural Science, NYU, [2]Department of Psychology, Hunter College, CUNY

Neurons in primary visual cortex (V1) have characteristics that link them to the processing of fundamental aspects of color perception, for instance enhanced sensitivity for the edges of colored objects. We examined human cortical responses to color patterns quantitatively by studying the chromatic visual evoked potential (cVEP) as a measure of neural activity. The stimuli were isoluminant appearance-disappearance checkerboards that were square-wave modulated (0.5s on, 1.5s off) from gray to color and back to gray. The patterns had chromatic excitation purities ranging from 0.03 to 0.53. The square stimulus field was 10° across and the checks were 18.75′. Luminance was 31.5 cd/m2. We recorded cVEPs with a 64-channel BioSemi system. Responses were signal-averaged (30 repeats) and Fourier-transformed. Cortical topography indicated that cVEPs were highly localized at electrodes near Oz, pointing to V1 cortex as the major source of these responses. This agrees with previous work that had indicated the cVEP is driven mainly by neurons in V1. cVEP peak amplitude grew rapidly with purity and then hit a ceiling response at relatively low purities. Notably, the cVEP waveform was non-linear; its time- to-peak was shorter with increasing excitation purity. The non-linear change in cVEP waveform was also seen as a phase-advance in most Fourier components of the response as color purity increased. Harmonic analysis of the cVEP also revealed that the amplitude spectrum of Fourier components of the cVEP in the 2-30 Hz range varied with color excitation purity; the spectrum shifted to higher temporal frequencies with increasing color purity. The spectral shift is another manifestation of color-contrast-dependent non- linear dynamics. Since the parvocellular LGN input to the cortex is known to be highly linear, the observed non-linear characteristics of the EEG response point to cortical nonlinearities.

32.17, *12:15 pm* **Decoding color constancy in fMRI** Elisabeth Baumgartner[1](baumgartnerelisabeth@gmail.com), David Weiss[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Giessen University

Our visual system is capable of achieving constant color perception across large changes in illumination. Consequently, a physically constant, colorimetrically neutral patch of light, appearing gray under a neutral illumination, will appear vividly colored if the observer has the impression that the illumination of the scene changed. We wanted to test whether we can decode the brain's responses to color with respect to appearance, rather than mere retinal cone stimulation. We presented observers with a set of colored patches under three different simulated illumination conditions, while recording brain activity in a 3T fMRI scanner. Our stimuli consisted of a central square patch within a variegated surround. In neutral illumination trials, the surround remained neutrally illuminated while the central patches oscillated between gray and blue or gray and yellow. We used this neutral illumination condition to train a classifier to decode the central color patches into bluish and yellowish colors, based on the activity of the 300 most responsive voxels. These were obtained by means of a localizer that determined the retinotopic location of the target patches. Accuracies were between 50% and 79% correct (mean 67%). We then introduced simulated illumination changes. In these trials, the variegated surround oscillated between a neutral and either a bluish or a yellowish illuminant. This made the neutral gray patches appear to oscillate between gray and yellowish or bluish, respectively. When the classifier, trained on the real colors, was used to decode the appearance of these stimuli, accuracy was slightly reduced but still above chance (46% to 71%, mean 62%). Our results show color appearance can be decoded as early as V1/V2. This indicates that color constancy could be achieved very early in the visual pathways.

Acknowledgement: DFG-SFB/TRR 135

Motion: Biological motion and optic flow

Sunday, May 15, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Gerrit Maus

32.21, *10:45 am* **People perception: Attractiveness from shape and motion** Nikolaus Troje[1](troje@queensu.ca), Andreas Bieg[2], Naureen Mahmood[3], Betty Mohler[2], Michael Black[3]; [1]Department of Psychology, Queen's University, [2]Max Planck Institute for Biological Cybernetics, [3]Max Planck Institute for Intelligent Systems

While there exists plenty of work on facial attractiveness only little is known about how the rest of the body determines the perception of another person. We were particularly interested in how the shape of the body and the way it moves contributes to attractiveness. Observers (20 male and 20 female) rated the attractiveness of 50 men and 50 women from the BML database each displayed in either of three ways in a 3D immersive virtual reality: (a) static bodies reconstructed from the motion capture data by means of MoSh (Loper et al. 2014, SIGGRAPH Asia) displayed as detailed 3D shapes ; (b) walking stick-figures (Troje 2002, JOV); (c) same bodies as above, but animated with the corresponding walking movements. Correlations between all 12 sets of ratings (2 participant sex x 2 walker sex x 3 display types) reveal three different factors that contribute to the perception of attractiveness. The first factor is sexual dimorphism and applies to female attractiveness assigned to stick figures and moving meshes. The more feminine a woman, the more attractive she is rated. The second is characterized by increased vertical movement which makes the attractive walker appear bouncy, confident, and vigorous. It dominates male attractiveness assigned to stick-figures and moving meshes. The third factor is characterized by slim, tall body shape (attractive) as compared to stout and wider shapes and applies to ratings of static body shapes of both male and female walkers. Male and female observers agree in all cases. The way we move affects our appeal to others as much as the appearance of the static body. While sexual dimorphism dominates female attractiveness, it does not play much of a role for male attractiveness – neither in the shape nor in the motion domain.

Acknowledgement: NSERC

32.22, *11:00 am* **What are the underlying units of perceived animacy?: Chasing detection is intrinsically object-based** Benjamin van Buren[1](vanburenb@gmail.com), Tao Gao[2], Brian Scholl[1]; [1]Dept. of Psychology, Yale University, [2]Dept. of Brain and Cognitive Sciences, MIT

One of the most foundational questions that can be asked about any visual process is the nature of the underlying 'units' over which it operates — e.g. features, objects, or spatial regions. Here we address this question — for the first time, to our knowledge — in the context of the perception of animacy. Visual processing recovers not only low-level features such as color and orientation, but also seemingly higher-level properties such as animacy and intentionality. Even simple geometric shapes may appear to be animate (e.g. chasing one another) when they move in certain ways — and this appears to reflect irresistible visual processing, occurring regardless of one's beliefs. What are the underlying units of such processing? Do such percepts arise whenever any visual feature moves appropriately, or do they require that the relevant features first be individuated as discrete objects? Observers viewed displays containing several moving discs. Most discs moved randomly, but on chasing-present trials, one (the 'wolf') chased another ('the sheep'), by continually updating its heading in the direction of the sheep. On chasing-absent trials, the wolf instead chased the sheep's mirror-image (thus controlling for correlated motion). Observers' task on each trial was simply to detect the presence of chasing. Critically, however, two pairs of discs were always connected by thin lines. On Unconnected trials, both lines connected pairs of distractors; but on Connected trials, one line connected the wolf to a distractor, and the other connected the sheep to a different distractor. Signal detection analyses revealed that chasing detection was severely impaired on Connected trials: observers could readily detect an object chasing another object, but not a line-end chasing another line-end — even when both were easily discriminable. We conclude that the underlying units of perceived animacy are discrete visual objects.

32.23, *11:15 am* **Phenomenal Causality in Biological Motion Perception** Yujia Peng[1](yjpeng@g.ucla.edu), Steven Thurman[1], Hongjing Lu[1,2]; [1]Department of Psychology, UCLA, Los Angeles, California, United States of America, [2]Department of Statistics, UCLA, Los Angeles, California, United States of America

The "moonwalk", a renowned dance move, has fascinated people for decades. We hypothesize that the movement's impact is due to the surprise triggered by its violation of a fundamental expectation. Humans naturally assign the role of cause to relative limb movements, and the role of effect to body motion (i.e., limb movements cause changes of body position in the environment). The present study examined causal movements based on the ubiquitous expectation of causal asymmetry: an effect does not precede its cause. Action sequences were generated by shifting the temporal sequence of body positions relative to limb movements either ahead of time (i.e., effect precedes) or behind (i.e., cause precedes). Experiment 1 showed that actions with preceding limb movements were rated as more natural than actions with preceding body motion, suggesting the causal binding of two movement cues impacts perceived naturalness of actions. Experiment 2a explicitly separated the causal movements from the effect motion. A movie presented an actor walking on a treadmill conveyed relative limb movements (cause), while a moving dot signaled body position change over time (effect). We again found that participants were more likely to judge the two movements as matched when limb movements (cause) preceded body motion (effect) rather than vice versa. Experiment 2b used identical stimuli, except that participants were informed of the reversed cause-effect relation as a person aimed to track a moving laser spot. Observers now judged displays to be more natural when the dot movements preceded the limb movements, establishing that the temporal asymmetry effect is based on the understanding of the causal relation. Finally, we developed an observer model solely based on visual statistics of action stimuli. This model failed to account for the empirical findings, due to its lack of knowledge about the critical causal relations between the two movement cues.

Acknowledgement: NSF BCS-1353391

32.24, *11:30 am* **Constraint-based hierarchical motion analysis for biological movements** Hongjing Lu[1](hongjing@psych.ucla.edu); [1]Departments of Psychology and Statistics, UCLA

Movements of the human body are comprised of multiple motion components organized in a hierarchical manner. For example, the motion of a foot joint is nested within a moving leg, which is nested within a moving body. It remains unknown how humans discover the hierarchical structure representing bodily movements, and what fundamental constraints underlie the formation of motion structure. A non-parametric Bayesian model was developed to infer the hierarchical motion structures that can generate observed visual input. Many different hierarchical motion structures would be consistent with observed bodily movements, but three types of constraints sufficed to resolve ambiguity: a generic prior on object parsing (favoring simpler hierarchical structures), a generic prior on spatially smooth motion within a component (resulting from rigid movements of individual parts), and a body-specific constraint (certain joints move in coordination based on body structure). This generative model can account for a range of findings in the literature on biological motion perception, including better recognition performance for an upright than an inverted point-light walker, above-chance performance in discriminating walking direction for a spatially-scrambled and phase-scrambled walker (Troje & Westhoff, 2006, Exp. 2), the special contribution of foot movements in discriminating walking direction (Troje & Westhoff, 2006, Exp. 3), the variation in recognition accuracy across different action categories (Dittrich, 1993). The model also reveals how body structure interacts with the organization of motion components to form efficient action representations. When the body constraint was included in the formation of hierarchical structure, the representation space of actions was altered to cluster similar action types, but enlarge the distances of different actions. This finding suggests that the body constraint plays an important role in organizing motion information into a hierarchical structure, thereby increasing the representational power of an action space.

Acknowledgement: NSF BCS-1353391

32.25, *11:45 am* **Adaptation to human locomotion speed** George Mather[1](gmather@lincoln.ac.uk), Rebecca Sharman[1, 2]; [1]School of Psychology, College of Social Science, University of Lincoln UK, [2]Psychology Division, School of Natural Sciences, University of Stirling, UK

Visual judgments of human movement play an important role in social interactions, but relatively little is known about how retinal motion signals are used to estimate human movement speed. We report a new effect which demonstrates that these judgments are subject to modification by exposure to dynamic images. Participants viewed videos of real scenes depicting either groups of figures walking along a High Street or contestants running in the London Marathon. When video playback was speeded up or slowed down slightly relative to natural speed, participants could readily report whether the figures in each video appeared to be moving unnaturally quickly or slowly. However after adapting to slowed-down walking, natural walking speed appeared too fast, and after adapting to speeded-up walking, natural walking speed appeared too slow. Corresponding effects were found for running videos. Adaptation to natural-speed playback had no effect on apparent locomotion speed. These effects are quite different in a number of respects from those previously reported in studies of retinal velocity adaptation using simple patterns such as gratings. Unlike the stimuli used in most previous studies our videos contained a range of speeds and directions due to the unpredictability of natural scenes. Walkers and runners moved in different directions at different speeds, and at varying distances from the camera. Participants also engaged in free viewing rather than fixation. Furthermore over the range of retinal velocities our stimuli contained, adaptation to simple moving patterns causes a significant reduction in apparent velocity at all test velocities, including at the adapting velocity. Our data are consistent with the operation of a qualitatively different process in judgements of locomotion speed in natural scenes.

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32.26, *12:00 pm* **The interaction between local and global noise for optic-flow patterns** Alan Lee[1,2](alanlee.lingnan@gmail.com), Chu Ning Ann[1], Gerrit Maus[1]; [1]Division of Psychology, Nanyang Technological University, Singapore, [2]Department of Applied Psychology, Lingnan University, Hong Kong

Both the local and global stages of motion processing are susceptible to noise in the stimulus. Given the hierarchical nature of motion processing, how do the effects of local and global noise interact with each other? If such interaction exists, does it differ across different types of motion patterns? We addressed these questions using a novel psychophysical technique, in which uncertainty at the global and local stages of motion processing was independently manipulated within the same motion stimulus. We used a multiple-aperture motion pattern, which consisted of an array of randomly-oriented, drifting-Gabor elements (Amano et al., 2009). Global noise was manipulated based on motion coherence: Global signal-to-noise ratio (global-SNR) was defined as the ratio between signal and noise element numbers. Signal elements were assigned velocities consistent with a specific global motion direction, while noise elements were assigned velocities based on random global motion directions. Local noise was introduced by superimposing dynamic-noise pixels on each drifting Gabor patch at every motion frame. Local-SNR was defined as the ratio between the contrasts of Gabor patches and noise pixels. Observers performed a 2-choice, global-direction-judgment task on three optic-flow patterns: translational (left vs right), circular (clockwise vs counterclockwise), and radial (inward vs outward). In each block of trials, we fixed local-SNR and measured the 75%-accuracy threshold in terms of global-SNR. For all three optic-flow patterns, we found a "tradeoff" between local and global noise: Global-SNR thresholds decreased log-linearly as local-SNR increased, suggesting an interaction between local and global noise in the motion system. Above a certain local-SNR level, global-SNR thresholds remained constant. This saturation point was lower for circular motion compared to radial and translational optic-flow patterns, suggesting that global integration mechanisms for circular motion are more tolerant to disturbances from local noise.

32.27, *12:15 pm* **A neural model of MST and MT explains perceived object motion during self-motion** Oliver Layton[1](laytoo2@rpi.edu), Brett Fajen[1]; [1]Department of Cognitive Science, Rensselaer Polytechnic Institute, 110 8th Street, Troy, NY 12180

To avoid collisions, predation, and other life-threatening encounters, humans must perceive the motion of objects that move independently during self-motion. The local optical motion of such objects on the retina depends not only on their movement through the world, but also on the observer's self-motion (observer-relative reference frame). Yet, there is compelling evidence that humans perceive the object motion in a world-relative reference frame, that is at most weakly affected by self-motion (Matsumiya & Ando, 2009, Rushton & Warren, 2005; Warren & Rushton, 2009). The visual system must somehow transform the observer-relative motion on the retina to a world-relative reference frame. The importance of this problem has inspired research on the visual conditions in which object motion is recovered, but the underlying mechanisms in the visual system remain unclear. We present a simple model that makes explicit possible mechanisms in visual cortex by which self-motion signals in area MST interact with object motion signals in area MT to recover the world-relative motion of an object. The model relies on two mechanisms to explain and unify existing data. First, feedback from MSTd cells inhibits MT cells that signal motion that is inconsistent with the global flow pattern, which biases the direction coded by the MT population toward that of the object in a world-relative reference frame. Second, local antagonism between MT cells tuned in opponent motion directions leads to rebound activity that further shifts the MT population response toward the object's world-relative direction. Our analysis reveals the proportion that global and local mechanisms contribute in the recovery of world-relative object motion. The model clarifies the means by which self-motion and object motion signals might interact and offers a new hypothesis about the connection between heading and the recovery of object motion in a world reference frame.

Acknowledgement: ONR N00014-14-1-0359

Object Recognition: Categories, perception and learning

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.3001 **Rapid category learning: Naturalized images to abstract categories** Alison Campbell[1](campbel1@uvic.ca), James Tanaka[1]; [1]University of Victoria, British Columbia

Object categories are the perceptual glue that holds our visual world together. They allow us to recognize familiar instances and extend recognition to novel ones. Although object categorization has been studied using supervised learning techniques, less is known about how they are spontaneously acquired through unsupervised learning. In this study, we examined how temporal contiguity contributes to this spontaneous abstraction of object categories during passive viewing. We hypothesized that viewing exemplars of the same category closer in time would support better abstraction of the visual properties that distinguish one object category from another, and facilitate better category formation. Participants passively viewed a continuous sequence of 160 natural images of four warbler species (40 images per species). Images were presented serially for 500 ms per image with no visual masking. In a blocked condition, participants viewed images grouped by species (e.g., 40 images of Cape May warblers, followed by 40 images of Magnolia warbler, etc.). In a mixed condition, participants viewed images presented in random order. Participants then completed a "same/different" test using novel warbler images. A study image was presented for 500 ms, and then a test image was presented for 500 ms. Participants responded "same" if the images depicted warblers of the same species or "different" if they depicted different species. Participants in the blocked presentation condition performed reliably better on the same/different task (d' = 1.96) than participants in the mixed presentation condition (d' = 1.30, $p < .05$) and participants in a control condition who received no presentations prior to test (d' = 1.19, $p < .01$). Performance in the mixed presentation and control conditions did not reliably differ, $p > .10$. These results suggest that temporal contiguity may enhance the visual system's ability to rapidly extract statistical regularities involved in category learning.

Acknowledgement: Temporal Dynamics of Learning Center (NSF Grant #SBE-0542013), the Natural Sciences and Engineering Research Council of Canada (NSERC)

33.3002 **A Subjective Measure of Explicit and Implicit Category Rule Learning** Audrey Hill[1](audrey@knights.ucf.edu), Andrew Wismer[1], Corey Bohil[1]; [1]University of Central Florida

The neuropsychological theory of categorization known as COVIS (COmpetition between Verbal and Implicit Systems), postulates that distinct brain systems compete during learning of category rules (Ashby, Alfonso-Reese, Turken, & Waldron, 1998). The explicit learning system, mediated by the prefrontal cortex, involves conscious hypothesis testing about easily-verbalizable rules, while the implicit learning system, mediated primarily by basal ganglia structures, relies on procedural learning of rules that are difficult to verbalize. Although an enormous amount of behavioral data supports COVIS, it is unclear what participants understand about the category rule when it is learned implicitly. The current study was designed to gain a deeper understanding of the nature of implicit category rule learning. Using simple two-dimensional perceptual stimuli – lines of varying length and orientation -- participants were trained on either explicitly learnable rule-based (RB) or procedurally learned information-integration (II) category structures. Using an adaptation of Dienes & Scott's (2005) measure of unconscious knowledge, participants made trial-by-trial assessments attributing each categorization response to guessing, intuition (a marker of implicit learning), or rule use. Categorization accuracy for learners (>60% accuracy by end of training) was high in both conditions (~80%). Participants attributed substantially more responses to "rule" or "intuition" use than to guessing. Participants in the RB condition overwhelmingly gave the "rule" response compared to the "intuition" response. Participants in the II condition provided the "intuition" attribution significantly more than in the RB condition. These results provide a new form of support for the predictions of COVIS. The measurement scale provides valuable insight into learners' subjective understanding of implicitly-learned classification rules.

33.3003 **Improving Categorization Training with Structure-Sensitive Scheduling** Brett Roads[1](brett.roads@colorado.edu), Michael Mozer[1]; [1]CU Boulder, Department of Computer Science and Institute of Cognitive Science

Previous work on visual category training has demonstrated that the sequence of training trials can influence learning outcomes. Studies have compared blocked presentations (multiple examples of the same category in a row) to interleaved presentation (switching between categories from trial to trial). For example, Carvalho and Goldstone (2014, Memory & Cognition) found that when categories are relatively dissimilar, blocking yields better generalization to novel exemplars, but when categories are relatively similar, interleaving is superior. Carvalho and Goldstone propose that learners focus on commonalities when two consecutive items are of the same category and on differences when two consecutive items belong to different categories. Leveraging their hypothesis, we develop a simple parameter-free probabilistic model of attention to stimulus dimensions. When presented with a sequence of experimental stimuli encoded as feature vectors, the model indicates the degree to which the discriminative features will be discovered. The model correctly predicts the empirical rank order of generalization performance across various experimental conditions. Using this model as a surrogate for a human learner, we search for stimulus sequences (schedules) that optimize learning. We consider schedules produced by a generalization of a Lévy flight—often used to model foraging—operating in the stimulus representational space. By explicitly utilizing category structure, our scheduling procedure is able to generate structure-sensitive sequences. Tuning the two free parameters of this scheduling procedure to optimize the performance of our surrogate, we show that the best schedule for dissimilar categories is blocking and for similar categories is interleaving. With this flexible framework, we can optimize training sequences for complex, hierarchical, and heterogeneous category structures. We report on experimental studies to validate the computational model and scheduling procedure.

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33.3004 **The role of category-specific global orientation statistics for scene categorization** Heeyoung Choo[1](heeyoung.choo@utoronto.ca), Dirk Walther[1]; [1]Department of Psychology, University of Toronto

Real-world scenes contain category-specific regularities in global orientations that correlate well with broad descriptions of scene content, such as naturalness and openness. Here we test the role of global orientation statistics for scene categorization behavior, using line drawings and photographs of real-world scenes. To this end, we selectively disrupted global orientation distributions or local edge coherence and briefly presented the modified scenes to observers, who were asked to categorize each image as beach, city street, forest, highway, mountain, or office. In Experiment 1, we disrupted global orientations of line drawings by random image rotation, local edge coherence by random contour-shifting, or both. We found that contour-shifting impaired categorization accuracy significantly more than image rotation. When line drawings were under both manipulations, scene categorization was the least accurate. These findings suggest that contour orientation contributes to accurate scene categorization, although less so than local edge coherence. In Experiment 2, we normalized the spectral amplitude of grayscale photographs either within a category to preserve category-specific global orientation distributions or across all six scene categories to remove them. We found that category-specific mean amplitude significantly improved participants' categorization accuracy. How does the distribution of category-specific global orientation affect representational structure of scene categories? Across the two experiments, we compared error patterns for manipulated images with those for the intact conditions. The results showed that the error patterns for the images with global orientations disrupted (image rotation, amplitude normalization within or across categories) showed significant correlation with error patterns for intact images. On the other hand, when localized edge coherence was disrupted (contour shifting with or without image rotation), error patterns did not match those for intact images. We conclude that category-specific global orientation distribution aids in accurate scene categorization, but that it has no impact on the categorical representations underlying human scene perception.

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33.3005 **Predicting categorical search behavior on individual trials using category-consistent features** Justin Maxfield[1](jmaxfieldsbu@gmail.com), Chen-Ping Yu[2], Gregory Zelinsky[1,2]; [1]Department of Psychology, [2]Department of Computer Science

In previous work we demonstrated that the search for a categorical target depends on the hierarchical level in which the target is cued. Targets cued at the subordinate level displayed an advantage in measures of guidance while basic-level cues were verified the fastest. The Category-Consistent Feature (CCF) model extracts the important features of a target category, computationally-defined as high-frequency and low-variability features across the category exemplars. This model predicted behavioral trends across hierarchical levels, but can it also predict search behavior on individual trials? Participants (n=26) searched 6-item displays for a text-cued target in subordinate (n=48), basic (n=16), and superordinate-level (n=4) conditions (68 categories in total). Targets and distractors were images of objects cropped from ImageNet and Google. The CCF model represents a category by averaging SIFT+color bag-of-words feature histograms of exemplars and using a signal-to-noise ratio to prune away the less informative features in the averaged histogram. The resulting category-specific CCF histogram is then compared to the raw feature histograms extracted from the target and distractors in the search display to derive a categorical priority map, which we use to predict behavior. Correlating these independent model predictions with search performance, we found that the CCF model successfully predicted both the time taken to initially fixate the target (target guidance) and the time needed to verify the target as a member of the cued category after its initial fixation (target verification). Importantly, we obtained these results in the context of a hierarchical structure spanning three levels, 68 categories, and 4,800 image exemplars, thereby demonstrating the robustness of our generative modeling approach. By using the CCF model to represent the within-category feature structure of common objects, it is now possible to predict categorical search behavior, not just in the aggregate, but on individual trials.

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33.3006 **Ecologically Valid Categorization and Best-Classifer Feedback** Sarah Williams[1](sarahwilliams@knights.ucf.edu), Andrew Wismer[1], Troy Schiebel[1], Corey Bohil[1]; [1]University of Central Florida

Classification training typically involves viewing a series of category examples, making a classification response to each, and receiving corrective feedback regarding category membership. Objective feedback (i.e., based on actual category membership) suggests that perfect accuracy is possible even when it may not be (e.g., overlap exists between categories). Previous research has shown this type of feedback can be detrimental to learning an optimal (long-run reward-maximizing) decision criterion by fostering excessive attention to trial-to-trial accuracy. Some accuracy must be sacrificed to maximize long-run reward (Bohil, Wismer, Schiebel, & Williams, 2015; Bohil & Maddox, 2003). Thus, it is important to consider other types of feedback for training, such as using the responses of an "optimal" performer to create feedback that indicates that using even the optimal response criterion produces occasional response errors. In the current study, normal or cancer-containing mammograms were used to assess how feedback influences classification. Participants earned more points for correct "cancer" than correct "normal" responses. Feedback was given in one of two forms: objective (based on actual category membership) or based on a "best" classifier (i.e., the responses of the nearest-optimal performer from an earlier classification study). Critically, the performance of an optimal or "best" classifier indicates that even when using the best possible classification criterion, errors should be expected, as opposed to objective feedback which implies 100% accuracy may be possible when it is not. Signal detection analyses indicated decision criterion values that were closer to optimal in the best-classifier condition. Participants trained with best-classifier feedback also had higher point totals and a reduction (as predicted) in overall response accuracy compared to participants trained with objective feedback. This work replicates earlier research using simple artificial stimuli, and shows that feedback reflecting a more-attainable performance level supports more optimal decision criterion placement and performance.

33.3007 **The Vanderbilt Car Memory Test (VCMT)** Mackenzie Sunday[1](mackenziesunday@gmail.com), Jennifer Richler[1], Isabel Gauthier[1]; [1]Department of Psychology, Vanderbilt University

Several studies using reliable measures of individual differences in object recognition with several object categories find that car recognition ability shares little to no variance with other object recognition abilities. In fact, car recognition is at least as independent from the recognition of other non-face categories as face recognition. Consequently, using cars to represent non-face objects may be problematic, especially when only one non-face object category is used. While the relative independence of car recognition ability has been replicated in several datasets, this result has only been obtained using learning measures that repeat stimuli across trials. This learning component common to every test in these datasets may moderate correlations between tests. For example, it may be that greater experience with cars leads to faster learning over trials within this category, leading to a dissociation with other categories that are learned more slowly. To test if the independence of car recognition generalizes outside of learning tasks, we created the Vanderbilt Car Memory Test (VCMT), which does not repeat stimuli across trials. The VCMT is modeled after the Vanderbilt Face Memory Test (VFMT). Each trial begins with 2 car images presented for 4 seconds, followed by a 3-AFC. We honed the test through 3 iterations to produce good internal reliability (approximately .85) with an average accuracy of approximately 60% (SD = 12%). This test, and similar tests with other non-face categories, will be useful to evaluate accounts of why car recognition ability is independent from the recognition of most other object categories.

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33.3008 **Sudden emergence of categoricality at the lateral-occipital stage of ventral visual processing** Alexander Walther[1](awalthermail@gmail.com), Joern Diedrichsen[2], Marieke Mur[1], Seyed-Mahdi Khaligh-Razavi[3], Nikolaus Kriegeskorte[1]; [1]MRC Cognition and Brain Sciences Unit, [2]Department for Computer Science, University of Western Ontario, [3]Computer Science and Artificial Intelligence Laboratory, MIT

The ventral stream is known to host low-level representations of visual objects in early visual areas and high-level representations emphasizing categorical divisions in more anterior regions. Here we compare similarity spaces among key functional regions to elucidate representational transformations across stages of processing. We performed high-resolution fMRI in 24 subjects to measure response patterns elicited by 62 images of isolated real-world objects (24 animate, 24 inanimate, 14 well-controlled faces) in V1, V2, V3, LOC, OFA, FFA, and PPA. For each pair of stimuli, we computed an unbiased estimate of their representational discriminability (linear discriminant t values) and assembled these estimates in a representational dissimilarity matrix (RDM) for each brain region. To quantify the relatedness and distinctness of regional representations, we computed a novel measure of noise-corrected shared and non-shared RDM variance. Early visual regions did not exhibit strong categorical structure, while representations became highly categorical in higher-level regions. Categoricality did not arise gradually along the ventral stream, but appeared suddenly at the stage of LOC and OFA, where faces, bodies, and inanimate objects formed distinct clusters. The same clusters were present in FFA, where the representation appeared to be of low dimensionality, and broke down in PPA, where scenes were distinct and all other images formed a single cluster. V1-3 shared most of their dissimilarity variance, as did LOC, OFA, and FFA, but V1-3 were significantly distinct from the category-selective regions. PPA was significantly distinct from V1-3 as well as LOC, OFA, and FFA. The ventral stream hosts object representations that are both related to and distinct from one another to different degrees. Our novel methods for inference on shared and non-shared dissimilarity variance contribute an important tool for understanding brain computations as transformations of representational spaces.

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Object Recognition: Features and parts

Sunday, May 15, 8:30 am - 12:30 pm

Poster Session, Banyan Breezeway

33.3009 **An Empirical Examination of Perceptual Integrality with both Non-parametric and Parametric Methods** Yanjun Liu[1](yanjun1130@gmail.com), Mohammad Abdolvahab[1], James Townsend[1], Michael Wenger[2], Lisa De Stefano[2]; [1]Department of Psychological and Brain Sciences, Indiana University Bloomington, [2]Department of Psychology, Cellular and Behavioral Neurobiology, University of Oklahoma

General Recognition Theory (GRT, Ashby&Townsend, 1986) is a powerful, static, nonparametric theory used to characterize the relationship between theoretical characteristics such as perceptual independence (PI), perceptual separability (PS) and decisional separability (DS), and response-frequency-based measures such as marginal response invariance (MRI). RTGRT (Townsend, Houpt, & Silbert, 2012) is a stochastic version of GRT that addresses both response frequencies and response times (RTs). The current study examines the extent to which GRT and RTGRT consistently capture the same relationships between in data. A complete-identification experiment

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with a feature-complete-factorial design using perceptually integral stimulus dimensions (Macmillan & Ornstein, 1998) was conducted to achieve this goal. Width and height of square/rectangular stimuli were varied with two levels of salience for each dimension. We predicted violations of PS, evidenced by violations of marginal response invariance (MRI) in the response frequency data and violations of timed MRI (tMRI) in the RT data. Further, we predicted that fits of parametric multidimensional signal detection models to the data would confirm the inferences drawn from the non-parametric measures. Results from the non-parametric measures suggested possible violations of PS, PI, and DS, as indicated by violations of both MRI and tMRI. Results from fitting the parametric models were consistent with these inferences and further suggested violations of PS in both dimensions for all subjects, and fulfillment of DS for three out of four subjects. The results in sum document the empirical consistency of GRT and RTGRT and suggest their utility in characterizing the perception of multidimensional forms.

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33.3010 **Object-location binding: Does spatial location influence high-level judgments of face images?** Michela Paradiso[1](paradiso.3@osu.edu), Anna Shafer-Skelton[1], Aleix Martinez [2], Julie Golomb[1]; [1]Department of Psychology, The Ohio State University, [2]Department of Electrical and Computer Engineering, The Ohio State University

To function in the world, our brains must integrate information about "what" objects are with information about "where" they are located. The Spatial Congruency Bias is a recent finding thought to reflect this binding between object and location information (Golomb et al., 2014). The bias demonstrates a strong influence of location information on object identity judgments; two objects are more likely to be judged as same identity when presented in the same location compared to different locations, even though location is irrelevant to the task. Previous results have found a Spatial Congruency Bias across a range of stimulus complexities: colors, Gabors, shapes, and faces (Shafer-Skelton et al., submitted). In this experiment, we tested the Spatial Congruency Bias for a more complex judgment: comparisons of facial expressions across facial identities. On each trial, a face was presented in the periphery. Next, a second face was presented with either the same or different expression, in either the same or different location. Facial identity was always different. Participants indicated whether the facial expressions were the same or different; stimulus location and facial identity were irrelevant to the task. Unlike the less complex tasks and stimuli, there was no bias of location on participants' responses of facial expression. To explore whether the lack of bias was due to the higher-level judgment or other differences from previous experiments, a second experiment was conducted in which participants compared expressions of two faces with the same identity (instead of across different identities), such that participants could now rely on low-level image differences as well. In this case, the Spatial Congruency Bias returned, with a similar magnitude to previous results. These results suggest spatial location can influence processing of objects and faces, but higher-level judgments may be more invariant to these effects, raising interesting implications for object-location binding.

Acknowledgement: NIH R01-EY025648 (JG), Alfred P. Sloan Foundation (JG), OSU Social and Behavioral Sciences Undergraduate Research Grant (MP)

33.3011 **Learning the 3D structure of objects from 2D views depends on shape, not format** Moqian Tian[1](moqiant@stanford.edu), Daniel Yamins[2], Kalanit Grill-Spector[1,3]; [1]Department of Psychology, Stanford University, Stanford, CA, [2]Department of Brain and Cognitive Sciences, MIT, Cambridge, MA, [3]Stanford Neuroscience Institute, Stanford University, Stanford, CA

Humans can learn to recognize new objects just from observing example views. However, it is unknown what structural information enables this learning. To address this question we manipulated the amount of structural information given to subjects during unsupervised learning by varying the format of the trained views. We then tested how format affected participants' ability to discriminate similar objects across views that were rotated 90° apart. We found that after training, participants' performance increased and generalized to new views in the same format. Surprisingly, the improvement was similar across line drawings, shape-from-shading, and shape-from-shading + stereo, even though the latter two formats provide richer depth information compared to line drawings. In contrast, participants' improvement was significantly lower when training used silhouettes, suggesting that silhouettes do not have enough information to generate a robust 3D structure. To test whether the learned object representations were format-specific or format-invariant, we examined if learning novel objects from example views transfers across formats. We found that learning objects from example line drawings transferred to shape-from-shading and vice versa. These results have important implications for theories of object recognition because they suggest that (1) learning the 3D structure of objects does not require rich structural cues during training as long as shape information of internal and external features is provided and (2) learning generates shape-based object representations independent of the training format.

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33.3012 **A deep neural net trained for person categorization develops both detailed local features and broad contextual specificities** Stella Yu[1](stellayu@berkeley.edu), Karl Zipser[2]; [1]Computer Science Department, UC Berkeley / ICSI, [2]Helen Wills Neuroscience Institute, UC Berkeley

A deep convolutional neural network was trained to classify person categories from digital photographs. We studied the specific tuning properties of nodes in this network at different hierarchical levels and explored the emergent properties when the network was connected as a recurrent system to optimize its visual input with respect to various high level criteria. The network design was borrowed from the GoogLeNet architecture and trained from scratch on 584 diverse person categories (e.g., economist, violinist, grandmother, child) from the ImageNet dataset. With the trained model we used gradient descent to generate preferred stimulus images for each convolutional node class in the network. At the first convolutional layer, these preferred images were simple grating patterns, monochrome or color, varying in orientation and spatial frequency and indistinguishable from the types of preferred images for the same network architecture trained on non-human categories. Nodes in the next two convolutional layers showed increasingly complex pattern specificity, without any recognizable person-specific features. Person-specific node were apparent in all subsequent convolutional layers. In the first layers where person-specific feature arise, they appear to be generic face detectors. In subsequent layers, detailed eye, nose and mouth detectors begin to appear, as well as nodes selective for more restrictive person categories — selective for age and gender, for example. At still higher levels, some nodes became selective for complete human bodies. The larger receptive fields of these higher level nodes provide the spatial scope for increasing degrees of context specificity: in particular, there are nodes which prefer a main human figure to one or more smaller figures in the background. These modeling results emphasize the importance of both facial features and figure ensembles in recognition of person categories.

33.3013 **How to Look Taller in Dressing: The Effect of Split Ratio in Height Perception** Hui-Ning Wu[1](sgkuai@psy.ecnu.edu.cn), Yi-Yun Sun[1], Shu-Guang Kuai[1]; [1]Key Laboratory of Brain Functional Genomics, Ministry of Education, Shanghai Key Laboratory of Brain Functional Genomics, School of Psychology and Cognitive Science, East China Normal University

The height perception of an object is affected by the layout of its subparts. The phenomenon triggers a great interest in the fashion industry to guide the dressing of people who are unsatisfied with their heights and eager to appear taller. Although fashion experts suggest many dressing tips to make people look taller, there is a lack of scientific evidence to support their claims. In this study, we used sophisticated psychophysics to investigate the illusion of height induced by split ratios and explored its application in fashion dressing. In the first experiment, we systematically measured the perceived height of a bar when it was split in the ratios of 9:1, 8:2, 7:3, 6:4, 5:5, 4:6, 3:7, 2:8 and 1:9. Our results found that a bar bisected in an unequal ratio was perceived taller than an equally-divided bar with the same physical length, and the bias became stronger as the magnitude of the asymmetry increased. Further experiment showed that the bias was due to the expansion of the longer part of the bar and the shrink of the shorter part in perception. Comparatively, the overestimation of the longer part was larger than the underestimation in the shorter part, inducing the overall bias of height perception. Finally, to test the ecological validity of the bias, we generated close-to-real models of human in a virtual reality environment. Participants were asked to judge the height of girl models when they were wearing skirts with different lengths. We found that wearing either a long or short skirt bisecting the leg into two asymmetric parts made the models looks taller, verifying the split bias in dressing. Our results indicate that asymmetric bisection induces the bias in height perception, supporting the applications of the rule in fashion dressing.

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33.3014 Feature-location binding, the "spatial congruency bias", and object-based attention Marina Barboza[1](m6barboza@gmail.com), Nonie Finlayson[1], Xiaoli Zhang[1], Julie Golomb[1]; [1]Department of Psychology. The Ohio State University

Successful visual processing involves combining information about object features and their spatial locations. Spatial attention is thought to play an important role in this binding process. However, it has been shown that attention is not only allocated to a specific spatial location (space-based attention) but can also spread across an object (object-based attention). Here we explored whether binding is sensitive to space-based or object-based effects, using a recent finding thought to reflect location binding called the spatial congruency bias (Golomb et al., 2014). The spatial congruency bias shows that when two stimuli are presented in the same location individuals perceive them as more similar in features/identity. We tested whether two stimuli are also perceived as more similar when contained within the same "object" compared to on different objects. Participants fixated at the center of a display with two rectangular frames representing two "objects" (as in Egly et al, 1994). A first stimulus (colored square) was presented on one end of one object and then masked; after a brief delay, a second stimulus was presented and masked. These two stimuli could be presented in the same exact location, a different location on the same object, or a different location on a different object. Importantly, location was irrelevant to the task, which was to judge same or different color. We replicated the spatial congruency bias such that two stimuli presented in the same location were more likely to be judged as the same color. Notably, we also found that participants were more likely to indicate that two stimuli were the same color when they were presented on the same object compared to being presented across different objects. These results suggest that both space-based and object-based effects influence the spatial congruency bias and may play a role in location binding.

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33.3015 Response Time Evidence for Perceptual Separability of Stimulus Dimensions Mohammad Abdolvahab[1,2](mabdolva@indiana.edu), Yanjun Liu[1], James Townsend[1], Michael Wenger[2], Lisa De Stefano[2]; [1]Department of Psychological and Brain Sciences, Indiana University Bloomington, [2]Department of Psychology, Cellular and Behavioral Neurobiology, University of Oklahoma

The present work extends a paradigm for studying independence and separability of perceptual dimensions by considering measures of reaction time. The paradigm is the complete identification task with a feature-complete factorial design, providing data for analyses within General Recognition Theory (GRT; Ashby & Townsend, 1996) and extended GRT including Response Times (RT-GRT; Townsend, Houpt & Silbert, 2012). We inquire as to whether perceptual separability of arc curvature and line orientation, as shown in previous studies (e.g. Kadlec & Hicks, 1998), can be validated through the dynamical analogues specified in RT-GRT. Specifically, we performed tests of timed Marginal Response Invariance (MRI) and Report Independence (RI) using RT data from four human subjects performing the complete identification task. Results of these non-parametric tests suggested consistent inferences with fits of parameterized multidimensional signal detection theory models. These results indicate, consistent with the predictions made using RT-GRT, that when the RT-based version of tests of independence and separability suggest that separability holds, response-frequency-based tests will support identical inferences. These outcomes emphasize the advantages of the theoretically-derived connections between the static and dynamic characterizations of perceptual independence, perceptual separability, and decisional separability and suggest the theoretical and empirical potential of this approach for investigations of perceptual organization.

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33.3016 Vertices are Effective in Perceptual Grouping (and Ungrouping) in Object Recognition Isabel Irawan[1](iirawan@usc.edu), Eshed Margalit[1], Sarah Herald[1], Irving Biederman[1,2]; [1]Neuroscience, University of Southern California, [2]Psychology, University of Southern California

"Classical" work in computer vision (e.g., Guzman, 1968) established that the grouping of surfaces to volumes in complex scenes—the key process in scene organization--could be achieved largely on the basis of constraints emanating from vertices where two or three contours co-terminate (Fig. 1). Surprisingly, with the focus on surface- or "appearance-based" models, there has been little research documenting the importance (or lack thereof) of vertices in shape-based object recognition, despite the extensive documentation that rapid object and scene perception can readily be achieved with line drawings. An L-vertex, the point at which two contours co-terminate, provides highly reliable evidence that a surface terminates at that vertex, thus providing the strongest constraint on the extraction of shape from images. In contrast, an X-vertex, where two contours cross without a change of direction at their crossing, provides no evidence for grouping and can thus be ignored in shape-based models of vision. 73 subjects named briefly presented line drawings of 56 objects in five conditions (Fig. 2): a) Intact (Original, O), b) OX, the Original with short line segments that crossed the contours to produce X-vertices, c) Contour Deleted (CD), the Original with gaps in each of the longer contours so that half of the original contour was deleted, d) CDX, the CD condition with short segments that crossed contours of the object thus producing X-vertices, e) CDL, the CDX condition with the segments shifted to the gap ends to produce L-vertices. Smooth continuation should allow grouping across the gaps, whether or not there were Xs present. Because the CDL condition bridges gaps with L vertices, each of which signals (inappropriately) the termination of a surface, it should interfere with the grouping of the object into a coherent whole, rendering identification difficult. This is what we observed (Fig. 3).

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33.3017 The effects of motion dynamics on the Ebbinghaus and Corridor illusions Ryan Mruczek[1](rmruczek@worcester.edu), Christopher Blair[2], Kyle Cullen[1], Kyle Killebrew[3], Annie Aguizzi[3], Gideon Caplovitz[3]; [1]Department of Psychology, Worcester State University, [2]Department of Psychology, McGill University, [3]Department of Psychology, University of Nevada, Reno

We recently demonstrated that image dynamics greatly enhance the Ebbinghaus Illusion (Mruczek et al., 2015 Front Hum Neurosci). We proposed that uncertainty in the representation of a target's angular size is a critical factor in determining the degree to which context influences its perceived size. Here, we extend our investigations of this target-specific 'uncertainty hypothesis' to the Corridor Illusion. The Corridor Illusion is predicated on the notion that the farther of two objects with identical angular sizes must be physically larger, and perceived size is modulated accordingly. Unlike for the Dynamic Ebbinghaus Illusion, the uncertainty hypothesis predicts a weaker effect of context if the target is moving in the context of the Corridor Illusion. Uncertainty as to whether the target maintains a constant angular size as it translates should reduce the need to perceptually correct for changes in perceived distance. To test this hypothesis, we constructed a Dynamic Corridor Illusion in which a target object moves back and forth along the floor of a corridor. Compared to Static versions with matched viewing conditions, we observed increased magnitudes for the Dynamic Ebbinghaus Illusion (replicating our previous findings) and decreased magnitudes for the Dynamic Corridor Illusion (Experiment 1: free-viewing, method of adjustment, Dynamic ~10%, Static ~20%, $p = 0.10$; Experiment 2: peripheral fixation, method of constant stimuli, Dynamic ~10%, Static ~25%, $p < 0.001$). Thus uncertainty in the angular size of the target (driven by stimulus dynamics) enhances contextual effects in the Ebbinghaus Illusion, whereas it decreases contextual effects in the Corridor Illusion. These results are inconsistent with a recent model proposing that the Corridor Illusion results from a target-independent, background-induced spatial shift in early visual cortex receptive fields (Ni et al., 2014 Curr Biol). Rather, our results highlight uncertainty-driven weighting of visual cues by neural circuits computing perceived object size.

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33.3018 Identifying Distinctive Features in Object Recognition Stephanie Roldan[1](sroldan08@vt.edu), Anthony Cate[1,2]; [1]Psychology Department, College of Science, Virginia Tech, [2]Center for Human-Computer Interaction, Virginia Tech

Studies of object recognition have identified two distinct modes of object processing: part-based, which relies on discrete local features, and holistic, based on global shapes and outlines. However, visual perception research often neglects to account for the contribution of highly informative local features to recognition achieved through either processing mode. In this experiment, 20 familiar and visually diverse real-world object photographs were divided into square segments of equal size. After providing labels for each whole object stimulus, participants (N = 20) viewed stimuli as they accumulated one segment at a time at the center of a computer monitor. Each segment configuration (500 ms) was preceded by a white fixation cross

(2 s) and followed by a white noise mask (300 ms). After each presentation, participants were asked to decide whether they could identify the object. If so, they were prompted to enter an identification label as provided during the preliminary naming task. A new image cue (1.5 s) then appeared on the screen and the presentation cycle began with a single segment of a new object stimulus. If the participant could not confidently identify the object, the presentation cycle repeated and the stimulus accumulated one additional segment at a time until it was identified. Each object stimulus completed 6 randomized accumulation sequences, yielding a total of 120 trials per participant. Data were analyzed to determine the modal frequency with which object segments appeared on-screen immediately preceding stimulus identification. Results revealed increased frequency for various segments across objects, suggesting that these visual regions may contain local features or properties that are relatively more informative than others. Furthermore, variation in frequency patterns observed across objects indicates that local feature saliency may be greater in certain stimuli. We predict these variations are related to holistic and parts-based processing of intact objects.

33.3019 **Nothing more than a curve: a common mechanism for the detection of radial and non-radial frequency patterns?** Gunnar Schmidtmann[1](gunnar.schmidtmann@mcgill.ca), Frederick Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Radial frequency (RF) patterns, which are sinusoidal modulations of a radius in polar coordinates, have been frequently used to study shape perception. Discriminating RF patterns from circles could be accomplished either by mechanisms sensitive to local parts of the pattern, or by a global mechanism operating at the scale of the entire shape. Previous studies have argued that the detection of RF patterns could not be achieved by local curvature analysis, but instead by a specialized global mechanism for RF shapes. Here we challenge this hypothesis and suggest a model based on the detection of local curvature to account for the pattern of thresholds observed for both radial and non-radial (e.g. modulated around a straight line) frequency patterns. We introduce the Curve Frequency Sensitivity Function, or CSFF, which is characterized by a flat followed by declining response to curvature as a function of modulation frequency. The decline in response to curvature at high modulation frequencies embodies the idea of a perceptual limitation for high curve frequencies. The CSFF explains the initial decrease in detection thresholds for low RFs followed by the asymptotic thresholds for higher RFs (Wilkinson, Wilson, & Habak, 1998) and similarly accounts for results with non-radial frequency patterns (Prins, Kingdom, & Hayes, 2007). In summary, our analysis suggests that the detection of shape modulations is processed by a common curvature-sensitive mechanism that is independent of whether the modulation is applied to a circle or a straight line and that therefore radial frequency patterns are not special.

33.3020 **Sensitivity to shape differences along morph spaces**
Nathan Destler[1], Manish Singh[1], Jacob Feldman[1]; [1]Rutgers

MOTIVATION. We investigated the dimensions defining mental shape space, by measuring shape discrimination thresholds along "morph-spaces" defined by pairs of shapes. Given any two shapes, one can construct a morph-space by taking weighted averages of their boundary vertices (after normalization), creating a continuum of shapes ranging from the first shape to the second. Previous studies of morphs between highly familiar shape categories (e.g. truck and turkey) have shown elevated discrimination at the category boundary, reflecting a kind of "categorical perception" in shape space. Here, we use this technique to explore implicit categorical boundaries in spaces of unfamiliar shapes, where categories are defined not by familiar named types, but by the underlying "generative" structure of mental shape space. METHODS. Subjects were shown two shapes at nearby points along a morph-space, and asked to judge whether they were the same or different, with an adaptive procedure used to estimate discrimination thresholds at each point along the morph-space. We targeted several potentially important categorical distinctions, such one- vs. two-part shapes, two- vs. three-part shapes, changes in symmetry structure, and other "qualitative" distinctions. RESULTS. The results show strong consistency between subjects, as well as some intriguing differences among different morph-spaces. In several spaces, subjects showed marked "categorical" discrimination patterns, with sensitivity (1/difference threshold) maximal at an intermediate point in the morph-space and declining near the two base shapes. However, in other morph-spaces, subjects showed high sensitivity near the base shape with the most symmetries, and declining sensitivity as asymmetry increased. CONCLUSION. The results show that discrimination thresholds are not uniform over shape spaces. Instead, categorical organization of shape spaces influences basic perceptual sensitivity to shape properties.

Attention: Individual differences

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.3021 **We aren't playing: No performance benefit for expert gamers in visual search for camouflaged targets** Alyssa Hess[1](alyssa.hess@knights.ucf.edu), Mark Neider[1]; [1]University of Central Florida

Is there an advantage for video game players (VGPs) over non-video game players (NVGPs) in attention and visual tasks? Research has sought to pit VGPs, or those trained on video games, against NVGPs in a growing number of cognitive and perceptual tasks. Yet, the literature remains divided over whether or not this advantage exists. Here, we compared search performance on a real-world visual search task for camouflaged targets between professional, nationally ranked VGPs (all from the fighting game genre) and NVGPs. We used eye tracking to characterize oculomotor behavior so that we could explore potential search strategy variations between VGPs and NVGPs. While it has been argued that VGPs can extract more visual information than NVGPs per fixation (which would predict similar patterns of eye movements between VGPs and NVGPs) (Dye et. al, 2009; Green & Bavelier, 2006), other findings suggest that VGPs instead employ search strategies that are different from NVGPs (Clark, Fleck & Mitroff, 2011). We found no differences in accuracy or reaction time (RT) between groups (in omnibus ANOVAs, all $p > .40$). However, we did find that the VGPs fixated more often and for shorter durations than NVGPs (all $ps < .05$). These differences in oculomotor measures suggest that while VGPs and NVGPs perform similarly in terms of overall aggregate performance measures in search for camouflaged targets, the manner in which they conduct their searches varies. Furthermore, we speculate that these oculomotor strategy differences might very well induce broader performance differences in easier, more traditional search tasks (Wu & Spence, 2013), and perhaps in other tasks that require selective attention (e.g., flanker task, enumeration, attentional blink) with which others have reported VGP advantages (Green & Bavelier, 2003).

33.3022 **The role of local attentional variations during eccentric view on the development of the preferred retinal locus of fixation**
Maria Barraza Bernal[1](maria.barraza-bernal@uni-tuebingen.de), Svenja Nill[1], Katharina Rifai[1], Susanne Trauzettel-Klosinski[2], Siegfried Wahl[1]; [1]Institute for Ophthalmic Research, Eberhards Karls University Tübingen, Germany, [2]University Eye Clinic, Tübingen, Germany

Sustained attention enhances perception of stimulus located at eccentric positions of the visual field. Perception is not equal for all eccentric directions, leading to topographic variations in attentional performance. Topographic variations found in normally sighted subjects are also valid after acquiring a macular scotoma. The chosen location of the preferred retinal locus of fixation (PRL) can be influenced by these topographic variations. In this study, the relation between the topographic sustained attention and the location of the developed PRL was investigated. Thirteen normally sighted subjects participated in the study. The sustained attention was measured in eccentric locations of the visual field using Manfred Mackeben´s paradigm (1999) and fixations were controlled using an eye tracker. Consequently, a 6° macular scotoma was simulated and PRL training was performed in a set of visual tasks during two one-hour sessions. The sustained attention measurement and the two simulations of macular scotoma were separated by at least 24 hours. Polar diagrams with the variations of the sustained attention in eight different directions showed that 77% of the subjects have a stronger attention performance in the horizontal meridian. Furthermore, after two hours of training, subjects developed a PRL. Finally, in five out of thirteen subjects, the directions with good attentional capabilities were candidates for the development of a PRL.

33.3023 **Sensitivity to perceptual similarity is associated with greater sustained attention ability** David Rothlein[1,2](david.rothlein@gmail.com), Joseph DeGutis[1,2,3], Michael Esterman[1,2,4]; [1]Boston Attention and Learning Lab, [2]VA Boston Healthcare System, [3]Harvard Medical School, [4]Boston University School of Medicine

Sustained attention is critical to daily functioning but the relationship between perceptual processing during sustained attention and the ability to remain focused is incompletely characterized. To explore this issue, we administered the gradual onset continuous performance task (gradCPT), a sensitive sustained attention task, to a large web-based sample (N>10,000, testmybrain.org). The gradCPT requires participants to respond to the majority of stimuli (cities-90%) and withhold to rare target images (mountains-10%). The images gradually transition from one to the next every

800ms, which eliminates the exogenous effects of abrupt stimulus onsets. By computing the pairwise pixel-image correlations of the stimuli across category (cities and mountains), we were able to assess which city exemplars were most "mountain-like" and which mountain exemplars were most "city-like". If perceptual representations influenced performance, we predicted that RTs for city images that were more "mountain-like" would be slower and "city-like" mountain images would be more prone to erroneous button presses. Consistent with our predictions, we found that the degree of cross-category similarity significantly correlated with RTs for cities (r=0.37; p< 0.0001) and erroneous button presses for mountains (r=0.44; p< 0.05). Furthermore, by computing the visual similarity of the top and bottom halves of the images separately, we revealed a bottom-half bias for cities and a top-half bias for mountains. Notably, individual differences in sensitivity to stimulus similarity were correlated with measures of ability (d-prime r=0.36; RT variability r=-0.44) and only weakly correlated with measures of strategy. In other words, individuals who displayed greater sustained attention ability were more likely to be influenced by stimulus similarity, suggesting enhanced perceptual processing is associated with greater sustained attention ability. Ultimately, stimulus similarity provides a new means to explore perceptual processing during sustained attention and could provide a novel behavioral marker for disorders of attention.

33.3024 **Multiple object tracking predicts math potential** Jeremy Wilmer[1](jwilmer@wellesley.edu), Paolo Martini[2], Laura Germine[3], Ken Nakayama[2]; [1]Psychology Department, Wellesley College, [2]Psychology Department, Harvard University, [3] Psychiatric and Neurodevelopmental Genetics Unit, Massachusetts General Hospital

With STEM education currently an international priority, efforts to isolate math-related aspects of human cognitive variation are of high interest. Here, we marshall the recruiting power of our citizen science project TestMyBrain.org to ask whether the classic experimental paradigm of multiple object tracking (MOT) can be used to capture math-related mechanisms of cognitive variation. We developed a brief (8-10 min), sensitive (Cronbach's alpha = .88), web-based MOT test and used it, along with other reliable (alpha > .80), well-validated tests to assess 19,724 participants (10,014 male) of varying ages (5th, 50th, and 95th percentiles 14, 25, and 58 years, respectively), educations (e.g. 34% of 25+ year olds had no more than a high school diploma), and ethnicities (46% non-Caucasian). Nearly two orders of magnitude larger than the entire prior literature on individual differences in MOT, this study represented an unprecedented opportunity to better understand how and why MOT performance differs across individuals. Four major findings emerged. First, MOT dissociated strongly from sustained visual attention (r(1930)=-.03) and vocabulary (r(2810)=-.09), indicating a remarkable cognitive specificity. Second, MOT associated strongly with spatial working memory (r(10841)=.44) and rapidity of spatial attentional switching (r(533)=.41), documenting MOT's validity as a core measure of visuospatial processing. Third, MOT robustly predicted SAT-math scores (r(2467)=.29), yet far less so SAT-verbal scores (r(2467)=.09), revealing a strong, specific connection to math potential. Fourth, STEM-majors scored substantially (up to 10-20 percentile points) higher on MOT than non-STEM-majors. Taken together, these findings indicate that our brief, web-based measure of MOT performance captures a core, math- and STEM-related aspect of visuospatial ability. We suggest that tests of MOT be considered a relevant, feasible addition to future studies of number cognition, quantitative abilities, and math/STEM education.

Acknowledgement: Brachman Hoffman Fellowship to JBW

33.3025 **Individual differences in subitizing range predict visual detection ability.** Joshua Eayrs[1](joshua.eayrs.13@ucl.ac.uk), Nilli Lavie[1]; [1]Institute of Cognitive Neuroscience, University College London

We used the load theory framework to test the hypothesis that an individual's 'subitizing' range (the number of items whose estimate can be made rapidly without serial counting) can be used to measure visual perception capacity. Previous findings that loading perceptual capacity results in reduced visual detection ability (Carmel et al. 2011, Macdonald & Lavie, 2008, Raveh & Lavie, 2014) led us to predict that a lower subitizing capacity would be associated with lower visual detection abilities. We tested this prediction in two experiments assessing individual differences in subitizing capacity and in visual detection tasks using the Inattentional Blindness and Change Blindness paradigms. In both experiments, participants performed a visual enumeration task consisting of estimating the number of randomly positioned black squares (from 1 to 9) presented briefly on-screen. In Experiment 1 participants also performed a modified Inattentional Blindness task (judging cross arm length while also detecting the occasional appearance of a small square shape). In Experiment 2 participants performed a change detection task requiring them to detect changes between flickering natural scene images (e.g. Rensink et al. 1997) in addition to the enumeration task. An individual's breakpoint from subitizing to counting (their subitizing range) was positively correlated with detection sensitivity in both the Inattentional Blindness (r= .31) and Change Blindness (r= .42) tasks. Multilevel regression demonstrated that subitizing range significantly predicts detection when controlling for counting accuracy in set sizes beyond the subitizing range. We conclude that an individual's subitizing range (as measured by the breakpoint of switching to counting) can provide an effective measure of their visual perception capacity and can be used to predict their visual detection ability.

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33.3026 **Visual and cognitive flexibility in artists** Rebecca Chamberlain[1](rebecca.chamberlain@ppw.kuleuven.be), Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, KU Leuven.

A growing amount of evidence suggests that artists have perceptual abilities which help them to achieve a range of depictive goals. Two sources exist to explain these perceptual abilities: bottom-up strategies that imply the existence of an 'innocent eye' (Ruskin, 1871) and top-down strategies that reflect stored representational schemas (Gombrich, 1960). The potential conflict between bottom-up and top-down strategies can be resolved if it is assumed that artists switch dynamically between perceptual representations in order to meet varying artistic task demands (Lou, 2015; Ostrofsky et al., 2012). However, there is little empirical research that tests this claim. An existing study showed that artists are better able to switch between global and local levels of visual stimuli (Chamberlain & Wagemans, 2015). The aim of the current study was to test artists' ability to switch between competing global perceptual representations in bistable figures. A sample of art-students (n=30) and non-art students (n=33) completed a series of drawing and perceptual tasks. Executive tasks testing inhibitory and switching abilities were also included to explore the cognitive corollaries of perceptual flexibility. It was found that artists were better able to switch between competing representations in bistable figures when asked to actively manipulate their representations. Artists' passive switch rates for bistable figures were no different from controls. Artists also showed a reduced switch cost in an executive function task although perceptual and cognitive flexibility were not correlated in the current study. These data demonstrate that artists possess the ability to selectively attend to different perceptual representations, providing support for the proposition that artists engage in different perceptual modes when creating works of art.

Acknowledgement: Research Foundation Flanders (FWO)

33.3027 **Increased influence of previously attended features in people with schizophrenia** Carly Leonard[1](cjleonard@ucdavis.edu), Benjamin Robinson[2], Britta Hahn[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 School of Medicine

During active vision, diverse factors such as current goals, target salience, and previous experiences interactively influence performance (e.g., Leonard & Egeth, 2008). Our understanding of impaired attentional functioning in people with schizophrenia is benefited by studies designed to isolate specific components of attentional guidance. In the current study, we examine intertrial influences in people with schizophrenia and matched controls using a popout visual search task (i.e., Maljkovic & Nakayama, 1994). Participants made a speeded response about the shape of a color singleton target, which was equally likely to be either a blue target object among red distractors or a red target object among blue distractors. Although the previous target color is irrelevant on the current trial, previous work has shown facilitated performance when the color of the current target repeats. We replicate that general pattern here. Critically, inverse efficiency scores, which combine accuracy and reaction time, show that people with schizophrenia are more greatly influenced by the color of the previous target than controls. In other words, they have a greater cost-benefit difference on the current trial as a result of a switched or repeated target color from the previous trial. The target color two-trials back similarly influenced both groups. Interestingly, visual working memory, as estimated in a separate task, was significantly correlated with intertrial influence, such that higher capacity individuals showed less evidence of carry-over effects. Overall, these results suggest that people with schizophrenia may be more prone to use recently attended features in the guidance of attention.

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 See page 3 for Abstract Numbering System

33.3028 **Anxious eyes: Does one's degree of social anxiety predict scene viewing behavior?** Gerald McDonnell[1](gmcdonnell@huskers.unl.edu), Michael Dodd[1]; [1]University of Nebraska - Lincoln

It has been repeatedly demonstrated that bottom-up and top-down factors influence the guidance of visual attention. However, only recently have researchers begun to examine the influence of individual differences relating to personality characteristics on attentional guidance (e.g., Risko, Anderson, Lanthier, & Kingstone, 2012). For instance, in a clinical population, autistic individuals exhibited decreased fixation durations to human faces compared to nonautistic individuals when viewing naturalistic scenes (Ribby & Hancock, 2008). To further examine this role of individual differences on oculomotor behavior in a healthy adult population, we examined whether one's degree of social anxiety predicts differential scanning strategies when presented with a visual scene. It was hypothesized that socially anxious individuals would spend less time fixating faces compared to their non anxious counterparts. Twenty-eight participants viewed a series of naturalistic city scenes, where at least one visible face was present in a scene. Participants' eye movements were monitored while they attempted to memorize each of the 40 images for a later memory test (no memory test was given). After completing the task, participants completed a battery of state and trait social anxiety measures. Interestingly, there were no differences across high and low socially anxious individuals in regards to dwell time and first fixation time to faces across the various city scenes. The current results provide preliminary evidence that anxiety does not impact goal-directed guidance of a scene.

33.3029 **Can attentional control settings explain differences in attentional bias to threat in anxious and non-anxious individuals?** Benedikt Wirth[1](benedikt.wirth@uni-saarland.de), Dirk Wentura[1]; [1]International Research Training Group 'Adaptive Minds', Department of Psychology, Saarland University, Saarbrücken, Germany

Usually, dot-probe studies find an attentional bias to threatening stimuli in anxious, but not in non-anxious participants. However, some studies applying the same or related paradigms report a significant attentional bias to threatening stimuli also in unselected samples. According to the contingent-capture theory of spatial cueing, attentional control settings are tuned to relevant target features to facilitate target detection. An irrelevant cue can therefore capture attention if it matches a relevant feature of the target. Thus, consistent with this theory, one can hypothesize that an attentional control setting tuned to threat is permanently active in anxious individuals but can also be activated in non-anxious individuals under certain conditions. In Experiment 1, we aimed to replicate typical contingent-capture effects employing temporal and spatial parameters commonly used in dot-probe tasks. Participants had to classify green or red schematic target faces that were preceded by either green or red cues. Consistent with the contingent-capture theory, we found significantly larger cueing effects for matching than for non-matching color cues. In Experiment 2, we changed the critical feature from color to threat. Now, participants had to classify schematic target faces that were preceded by two photographic cue faces, one angry and one neutral. The targets were either defined by their emotional valence (angry expression, i.e., matching condition) or by a non-emotional feature (i.e., non-matching condition). Participants' anxiety was assessed by the state-anxiety scale of the STAI. As expected, we found a non-anxiety-related attentional bias to angry faces when participants had to classify angry targets. However, we also found a non-anxiety-related attentional bias to angry faces of equal size when participants were searching for non-angry targets. This suggests that a bias to angry faces can be found in non-anxious participants, but that this bias is not contingent on attentional control settings induced by current task demands.

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Binocular Vision: Mechanisms and models

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

33.3030 **Human short-latency ocular vergence responses in the absence of the binocular disparity signal.** Boris Sheliga[1](bms@lsr.nei.nih.gov), Christian Quaia[1], Edmond FitzGibbon[1], Bruce Cumming[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, NIH

We studied human short-latency vergence eye movements to sine wave stimuli moving in opposite directions (left vs. right; up vs. down) in the two eyes. The sine wave seen by each eye underwent a ¼-wavelength shift each successive video frame (at 150 Hz stimulus refresh rate). This arrangement eliminates changing disparity cues because the phase difference between the eyes alternated between 0° and 180°. We, nevertheless, observed robust short-latency vergence responses, whose sign was consistent with the interocular velocity differences. These responses were strongest for spatial frequencies (SFs) in the range of 0.42-0.62 cpd, much higher than the optimal SF for evoking either ocular-following (OFR) or disparity-vergence (DVR) responses. Restricting the images seen by each eye to just half of the visual hemifield, such that there was no binocular image overlap, weakened but by no means eliminated the responses. Further spatial separation of images seen by the two eyes did reduce the responses. However, even with a spatial gap of 4 sine wave periods responses were still significant. Observations with sine wave stimuli were corroborated using moving uncorrelated white noise stimuli: the lowest tested speeds of motion—mediated by high-SF channels (see Sheliga et al., JOV in press)—were the most effective in eliciting the ocular vergence responses. Our results show that the short-latency ocular vergence can be evoked by interocular velocity differences in the absence of the binocular disparity signal. The responses to differences in interocular vertical velocity presumably reflect the responses to such stimuli recently shown in area MT (Czuba et al., 2014), for which no other behavioral consequence was previously known.

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33.3031 **Monocular gain control explains dichoptic benefit in binocular global motion perception** Lanya Tianhao Cai[1,2](tcai@sunyopt.edu), Alexander Yuan[1], Benjamin Backus[1,2]; [1]Graduate Center for Vision Research, SUNY College of Optometry, [2]SUNY Eye Institute

When viewing random-dot kinematograms (RDKs), percent coherence thresholds for global motion perception are lower if signal and noise dots are presented to different eyes (Cai, Yuan, and Backus, VSS 2015). This dichoptic benefit might come about either from monocular gain control (MGC) -- more dots in the noise eye causing each noise dot to be less effective -- or from monocular bias in global motion integrators (MBGM). The roles of MGC and MBGM can be tested by comparing performance in two conditions: a "binocular" condition that has same number of signal and noise dots in each eye (no overlapping), and a "biased-binocular" condition that has same number of dots in each eye but signal all in one eye. If MBGM occurs, then putting all signal in one eye should be beneficial. But if MGC alone was responsible for the previously observed dichoptic benefit, then this benefit should disappear in both conditions. We therefore measured percent coherence thresholds in four conditions: "monocular" (all dots in one eye), "dichoptic" (signal in one eye, noise in the other), "biased-binocular", and "binocular". We tested 6 subjects with normal vision in a forced-choice net motion discrimination task with 100 dots using a stereoscope. Threshold was estimated using a 3-down-1-up staircase procedure. A brief display (300 ms) of two-frame dot motion at 30 Hz was used to minimize selective tracking. Trials from different conditions were intermixed. All subjects performed similarly in the "monocular" and "binocular" conditions but significantly better in the "dichoptic" condition, which replicated the previous finding. Performance in the "biased-binocular" condition was significantly worse than "dichoptic", although still better than "binocular" with marginal significance. We conclude that the dichoptic benefit during binocular RDKs motion tasks appears to be explained mostly by MGC. More evidence is required to definitively confirm or rule out MBGM.

33.3032 **Perceptual thresholds are better in individuals with lower trial-by-trial neural variability** Ayelet Arazi[1,2](ayeletaraz@gmail.com), Nitzan Censor [3], Ilan Dinstein[1,2,4]; [1]Department of brain and cognitive science, Ben Gurion University of the Negev, Israel, [2]Zlotowski center for neuroscience, Ben Gurion University of the Negev, Israel, [3]School of psychological sciences and Sagol school of neuroscience, Tel Aviv University, Israel, [4]Department of psychology, Ben Gurion University of the Negev, Israel

Introduction The mammalian brain is a remarkably unstable system where neural responses to repeated presentations of an identical stimulus exhibit considerable trial-by-trial variability. Previous electrophysiological studies have shown that the presentation of a stimulus reduces trial-by-trial neural variability in comparison to ongoing neural variability present before stimulus onset. While the post-stimulus reduction in variance has been reported as a general property of neural responses, its potential impact on perception remains unknown. Here, we examined the relationship between the intensity of trial-by-trial neural variability in individual subjects and their contrast discrimination thresholds. Methods Twenty-two subjects performed a two alternative forced choice contrast discrimination task while their brain activity was recorded with EEG. We estimated the contrast discrimination threshold and the slope of the psychometric function for each subject. Trial by trial variability of the EEG recording was quantified before and after stimulus presentation to estimate the relative change in neural variability of each subject. Results Our results revealed that trial by trial variability is reduced ("quenched") by approximately 40% after stimulus onset in comparison to the ongoing variability present in the pre stimulus interval. We found negative correlations between individual levels of quenching and individual discrimination thresholds as well as positive correlations between individual levels of quenching and psychometric function slopes. Participants with larger reductions in neural variability exhibited lower discrimination thresholds and higher psychometric function slopes. Conclusions In agreement with the general principles of signal detection theory, these results suggest that individuals with sensory systems that quench trial-by-trial neural variability to a larger extent are likely to have better and more stable perceptual performance.

33.3033 Short-term ocular dominance plasticity: no role for color?

Kathy Mullen[1](kathy.mullen@mcgill.ca), Jiawei Zhou[1], Yeon Jin Kim[1], Alexandre Reynaud[1], Robert Hess[1]; [1]McGill Vision Research, Dept. of Ophthalmology, McGill University

Temporarily depriving one eye of its input, in whole or in part, may result in transient changes in ocular dominance and contrast detection thresholds, with the patched eye becoming stronger and more sensitive and the unpatched eye weaker and less sensitive. Here we address two distinct questions about the role of color vision in these plastic changes. First, we ask whether the target effects of eye deprivation are selective or broadband, for example, whether changes in ocular dominance differentially affect stimuli defined by achromatic as opposed to color contrast. Second, we determine the selectivity of the process driving the inter-ocular plastic changes, asking whether chromatic contrast, in comparison to achromatic contrast, is effective in changing ocular dominance. In experiments 1 and 2, we compare the effects of generalized deprivation on chromatic and achromatic test stimuli, using a translucent occluder over one eye for 2.5-hours. This produced changes in ocular dominance, measured using a dichoptic phase combination paradigm (Zhou et al., 2013, J. Vision, 13(12)), and changes in contrast thresholds that are similar in magnitude and time course for chromatic and achromatic test stimuli. In experiments 3 and 4, we use a dichoptic movie-viewing paradigm (Zhou et al., 2014, Proc. Biol. Sci., 281) to investigate the role of color versus achromatic contrast in driving these effects. We show that a color contrast imbalance between the eyes (uni-ocular chromatic deprivation) is not sufficient to produce changes in ocular dominance for chromatic test stimuli. However, an achromatic imbalance with no chromatic imbalance (uni-ocular achromatic deprivation) causes a generalized change in ocular dominance that affects both chromatic and achromatic test stimuli similarly. We conclude that an interocular imbalance in achromatic contrast, and not chromatic contrast, drives plastic changes in ocular dominance, however, these changes apply unselectively to both chromatic and achromatic responses.

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33.3034 Active stereo fixation: developmental influence on the binocular visual system

Agostino Gibaldi[1](agostino.gibaldi@unige.it), Andrea Canessa[1], Silvio Sabatini[1]; [1]DIBRIS, University of Genova, Italy

INTRODUCTION - The statistical properties of natural images has been proven to be effective in explaining a number of psychophysiological features of the human visual system related to the perception of different visual parameters (see [1], as review). Accordingly, neural-coding theory predicts that regularities in the environment should be exploited by the visual system for an optimal allocation of the required computational resources. METHODS - If other works analyzed the statistical characteristics of stereoscopic perception (see [2], as review), here, we specifically focus on investigating the possible role played by active binocular fixation strategies. By exploiting a unique experimental setup, which consists of a set of naturalistic three-dimensional images (disparity maps and stereoimage pairs) and a VR simulator, we differentiated between random fixations and actual binocular exploration of human subjects. The resulting statistics of retinal disparity were exploited to predict the functional characteristics of binocular vision, namely the retinal corresponding points (RCP), the cortical magnification factor (CFM), the empirical horopter, and the Panum's fusional area. RESULTS - At a first glance, there is a general compliance with psychophysiological findings for what concerns the shape of the empirical horopter and Panum's area, as well as perceptual correspondence of the patterns of RCP and CFM. Specifically, the subjects' disparity distribution allows for a more precise prediction of the functional characteristics of binocular vision. Moreover, the significant difference arising in active binocular fixations between central and peripheral field of view reveals a preference for crossed disparity, which can be interpreted as the binocular counterpart of the figure-ground segregation process, which is prominent in natural vision [3]. CONCLUSION - The obtained results assess the possible role of the fixation strategy on the evolution and development of the functional structure of the human visual system. [1] Geisler. Annu.Rev.Psychol., 2008 [2] Sprague. Science Advances, 2015 [3] Cottereau., J.Neurosci, 2011

33.3035 Dichoptic imbalance of luminance and its effects on the phase component of steady-state EEG signals

Bruno Richard[1](bruno.richard@york.ac.uk), Eva Chadnova[2], Daniel Baker[1]; [1]Department of Psychology, The University of York, [2]McGill Vision Research, Department of Ophthalmology, McGill University

A neutral density (ND) filter placed before one eye will produce a dichoptic imbalance in luminance, which attenuates responses to visual stimuli and generates a lag in neural signals from retina to cortex in the filtered eye (Wilson & Anstis, 1969, Am J Psychol, 82, 350-358). This, in turn, can induce disparity cues that lead to an illusory percept of depth (e.g., the Pulfrich effect). Here, we explored how the increased latency of the filtered eye alters neural responses to stimuli presented either monocularly or binocularly. We measured steady-state (SSVEPs) contrast response functions from the occipital pole at 6 different contrast values (0 to 96%) with 3 cycles/° sinusoidal gratings flickering at 5 Hz. To manipulate the balance of luminance between the eyes, neutral density filters (0.6, 1.2, and 1.8 ND) were placed in front of the dominant eye of observers while stimuli were presented at maximum contrast either to the filtered eye or to both eyes. The amplitude component of SSVEPs increased monotonically as a function of stimulus contrast and decreased as a function of filter strength in both monocular and binocular viewing conditions. For monocular stimuli, the ND filter increased the lag of the phase component of SSVEPs, up to a latency of 63 ms (95%CI +/- 31ms) at a filter of 1.8 ND. However, under binocular conditions, no apparent phase lag in the SSVEPs could be identified. This is indicative of a binocular combination process that suppresses the lagged input from the filtered eye. We explain these data with a computational model that implements a variable temporal impulse response function placed prior to a binocular contrast gain control mechanism, which, under binocular viewing conditions, suppresses the attenuated and lagged responses of the filtered eye. This model, additionally, offers insight on interocular interactions that may occur in amblyopia.

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33.3036 Ocular dominance plasticity tested with non-contrast based (kaleidoscopic) monocular deprivation

Mahalakshmi Ramamurthy[1](zz.maha@gmail.com), Erik Blaser[1]; [1]Developmental and Brain Sciences program, Department of Psychology, Human Vision Laboratory, University of Massachusetts, Boston

Introduction. Ocular dominance - influenced by mutual inhibition between the monocular streams and the weight given to each during binocular combination - exhibits plasticity, where monocular deprivation can bias dominance. Notably, short-term deprivation, counter-intuitively, biases dominance in favor of the deprived eye (as measured by binocular rivalry duty cycles, as well as dichoptic motion coherence, phase, and contrast discrimination thresholds). While these effects have been well-modeled by contrast gain changes, it is not clear whether the trigger to plasticity - the deprivation itself - need be contrast-based; all deprivation studies thus far have used light-tight patches or optical diffusers that obliterate contrast. In this study, monocular deprivation was induced with a 'kaleidoscopic' lens that obliterated coherent form and behavioral relevance, but preserved color, spatial frequency, and contrast. Method. 10 observers underwent short-term (2.5 hour) kaleidoscopic deprivation, and, as a baseline, light-tight deprivation (during a separate visit). Subjects performed a pre- and post-deprivation global motion coherence task dichoptically, with signal and noise dots presented to different eyes using LCD goggles - to measure ocular dominance. Results. Overall, in line with previous studies, light-tight deprivation significantly enhanced motion coherence sensitivity in the deprived eye (7% drop in threshold motion coherence; SE: 0.015; two-tailed t-test: 4.532; p=0.001). Kaleidoscopic deprivation showed similar, but non-significant trends (about a 4% drop), but these overall measures obscure considerable individual differences (with 7 of 10 observers showing enhancement, 1 suppression, and 2 no effect with light-tight deprivation, and 5 of 10 showing enhancement, 3 suppression, and 2 no effect with kaleidoscopic). Conclusions. Kaleidoscopic deprivation is sufficient to trigger ocular dominance plasticity in some observers, similarly to light-tight deprivation, but further tests are required (and ongoing) to determine the ubiquity of the effect and the source of individual differences.

33.3037 **Dichoptic imbalance of luminance affects the phase component of steady-state MEG signals** Eva Chadnova[1](eva.chadnova@mail.mcgill.ca), Alexandre Reynaud[1], Simon Clavagnier[1], Robert Hess[1]; [1]McGill Vision Research - Dept. Ophtalmology - McGill University

Interocular interaction in a normal visual system occur under dichoptic conditions when contrast and luminance are imbalanced between the eyes. Psychophysically such interaction are well described by a contrast normalization model. However the neural processing underlying such interactions within the visual cortex are still unclear. We set to investigate how an interocular imbalance in contrast or luminance affects visual processing. We used magnetoencephalography to record SSVEP and fMRI to obtain individual retinotopic maps that we used for source computation for each participant. Monocular and dichoptic stimuli (binary noise patterns) were frequency-tagged at 4 and 6 Hz (contrast modulated) and presented at a range of contrasts from 0 to 32%. Monocularly, we reduced the luminance by placing a 1.5 ND filter over one eye in the maximal contrast condition. We used amplitude component of SSVEP averaged per region of interest to describe monocular responses and dichoptic interaction. Phase component (phase angle and its variance) of the strongest vertex per region of interest was used to obtain the temporal estimate of the response. Monotonic increase in SSVEP amplitude reflected the experimental change in contrast from 0 to 32% in V1, V2, V3 and V4. Interocular suppression was seen in both eyes as a decrease in SSVEP amplitude and was well approximated by the normalization model (r2 =0.9). Reducing the mean luminance delayed monocular processing by approximately 35 ms across the areas of interest and increased phase variance. A dramatic increase in phase variance was observed in dichoptic condition for a monocular reduction in luminance. Delaying monocular input also increased suppression from the fellow-fixing eye to the delayed filtered eye and a release of suppression was seen in the opposite direction. Temporally filtering the monocular input prior to binocular combination stage of the normalization model provided a good fit to our experimental data.

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33.3038 **Suppression causes a complete breakdown in contrast constancy in amblyopes** Alexandre Reynaud[1](alexandre.reynaud@mcgill.ca), Robert Hess[1]; [1]McGill Vision Research - Dept. of Ophtalmology - McGill University

Amblyopic patients have a deficit in visual acuity and contrast sensitivity in their amblyopic eye as well as suppression of the amblyopic eye input under binocular viewing conditions. In this study we wanted to assess, in normals and amblyopes, the contribution of the two eyes' input under binocular and monocular viewing. For this purpose, using a suprathreshold contrast matching task in which the eyes were stimulated either simultaneously or successively, we measured the binocular balance across spatial frequency and compared it with the contrast threshold sensitivity ratio measured with the same stimuli in both controls and amblyopes. First, we observed that the binocular matching became more imbalanced at high spatial frequency for amblyopes compared with controls. Second, this imbalance did not depend on whether the stimuli were presented simultaneously or successively in the two groups. Finally, for both modes of presentation, the matching balance correlates well with the interocular threshold sensitivity. To conclude, the form of the perceived suprathreshold contrast imbalance as a function of spatial frequency can be solely explained by the interocular threshold sensitivity ratio in amblyopia. This suggests a complete breakdown of contrast constancy previously reported (Hess & Bradley, Nature, 1980) under purely monocular conditions, adding weight to the argument that the reduced sensitivity at and above threshold has a common cause, namely binocular suppression.

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33.3039 **Amblyopic suppression is not explained by signal attenuation** Jiawei Zhou[1](jiawei.zhou@mail.mcgill.ca), Alexandre Reynaud[1], Rong Liu[2], Yifeng Zhou[2], Robert Hess[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Montreal, Quebec, Canada, H3G 1A4, [2]CAS Key Laboratory of Brain Function and Disease, and School of Life Sciences, University of Science and Technology of China, Hefei, Anhui, PR China, 230027

The current model of amblyopic suppression is that it follows as a consequence of normal dichoptic masking where there is an attenuation to the input from the amblyopic eye. We directly test this by measuring and compensating for the signal attenuation in a dichoptic-masking paradigm. Using a qCSF approach, we measured individual's monocular CSFs when the untested eye saw a mean luminance background and when the untested eye saw a band-pass filtered noise whose peak spatial frequency was matched to that of the test grating. Interocular suppression was quantified by the difference in thresholds occurring between these two conditions for each eye. To factor out any signal attenuation by the amblyopic eye, the contrast of the noise mask was always matched in visibility: it was set at five and ten times the threshold of the untested eye. Due to a contrast ceiling effect, we narrowed our analysis to the frequencies where this matched visibility for our noise stimuli could be achieved. We found that, for normals, the two eyes exhibit symmetric suppression. However, in amblyopes, the amblyopic eye exerted significantly less suppression than the nonamblyopic eye, even though the contrast attenuation for the amblyopic eye had been accounted for. Furthermore, the suppression from the nonamblyopic eye to the amblyopic eye was not significantly different to that found in the normals. Similar conclusions were reached for noise stimuli that were 10x threshold for normals and amblyopes. We conclude that amblyopia involves asymmetric interocular suppression not accounted for by the known elevation in contrast threshold of the amblyopic eye. The nonamblyopic eye exhibits the expected dichoptic masking suppression of the amblyopic eye but the amblyopic eye exhibits much less counter suppression of the nonamblyopic eye. This imbalance leads to dominance by the nonamblyopic eye under binocular viewing.

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33.3040 **2-D coordinate frames for optic flow and disparity** Andrew Glennerster[1](a.glennerster@reading.ac.uk), Jenny Read[2]; [1]School of Psychology and Clinical Language Sciences, University of Reading, UK, [2]Institute of Neuroscience, Newcastle University, UK

Optic flow and binocular disparity both describe changes in the visual direction of features when the optic centre translates (over time or from the left to right eye) and the eye rotates. However, different conventions have developed for describing this flow field, e.g. dividing it into 'horizontal' and 'vertical' disparity, which has no equivalent in the optic flow literature. Here, we ask whether there are principled grounds to use any particular 2-D coordinate system to describe retinal flow in general. We examine the special circumstances that apply to animals, in which the observer fixates a point as they move, and we explore the situations in which the epipole (e.g. direction of heading) is close to the fixation point or approximately 90 degrees away (as is commonly the case for binocular disparity). Any general formulation should include both. Flow in the direction of epipolar lines depends on local surface structure, whereas flow in the orthogonal direction does not. However, these directions are not fixed on the retina and so cannot be the basis of a 2-D retinal coordinate frame, despite the fact that binocular torsion goes a long way to keeping these directions constant at the fovea for different binocular eye positions. We argue that it can be helpful to divide retinal flow into radial flow (with respect to the fovea) and non-radial flow (e.g. Weinshall, 1990), because flow in these directions, respectively, carries information about (i) the component of optic centre translation towards the fixated point (whether this translation is the inter-ocular separation or observer motion) and (ii) the perpendicular component of translation. This division of retinal flow or disparity may be just as useful, we argue, as any division based on 'horizontal' and 'vertical' disparity and would avoid any discussion about a suitable definition of such terms.

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33.3041 **Testing the binocular energy model with response variability** Sid Henriksen[1,2](s.henriksen@ncl.ac.uk), Jenny Read[2], Bruce Cumming[1]; [1]Laboratory of Sensorimotor Research, National Institutes of Health, [2]Institute of Neuroscience, Newcastle University

The binocular energy model (BEM) has proven to be a very successful description of disparity selective neurons in area V1. However, most tests of the model compare mean responses to different stimuli - little attention has been given to the distribution of responses predicted by the BEM. To explore the distribution of responses, we computed the responses of BEM units to dynamic 1D noise stimuli at a range of disparities, with either positive or negative binocular correlation. Each frame was presented for 30 ms. The distribution of the model's responses to these stimuli was highly kurtotic, similar to an exponential distribution. As for exponential distributions, the variance grows with the square of the mean, meaning that the Fano factor (variance/mean) in the model is proportional to the mean. This is in stark contrast to cells in V1, where the Fano factor depends only weakly on the mean. This means that disparity-related changes in the mean response of linear-nonlinear models are largely caused by a small number of frames which elicit very large responses, rather than, for example, reflecting a change in the mean of a Gaussian distribution. We show that the dependence of Fano factor on disparity holds even for linear-nonlinear cascade models of binocular cells that have been fit to real cells using recently developed optimization techniques. Importantly the neuronal data (to which the models were fit) do not show the same dependence of Fano factor on disparity. We show that it is possible to greatly reduce the Fano factor variation in the model by introducing a form of monocular gain control. We propose that incorporating monocular gain control is critical for adequately modeling the trial-to-trial dynamics of disparity-selective cells in V1.

33.3042 **The neural basis of stereomotion scotomas** Martijn Barendregt[1,2](m.barendregt1@uu.nl), Serge Dumoulin[1], Bas Rokers[2]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, The Netherlands, [2]Psychology, University of Wisconsin-Madison, USA

Many observers experience difficulty discriminating the direction of binocular motion through depth in part of their visual field. These regions of stereomotion blindness have traditionally been termed stereomotion scotomas. While we have previously shown that these scotomas are not the result of any monocular deficit, the underlying cause remains unknown. Here we investigate two potential neural impairments that could underlie this deficit: failures in processing changes in binocular disparity (CD) and interocular velocity differences (IOVD). We assessed the sensitivity to stereomotion across the visual field in observers with a stereomotion scotoma. Subsequently, we measured the sensitivity across the visual field to each of the two neural mechanisms, CD and IOVD, individually. Lastly, we measured BOLD responses using ultra-high field MRI (7T) elicited by viewing stereomotion stimuli presented in different locations in the observer's visual field. We find that at the spatial scale at which these visual impairments occur, the processing of binocular disparity is unimpaired, but the changes in binocular disparity contribute little to the perception of motion through depth. Sensitivity to IOVD, on the other hand, varies systematically with locations of stereomotion scotomas in the visual field. Further, we find that several early visual areas show a difference in the BOLD response to stereomotion stimuli when comparing responses within and outside the stereomotion scotoma. Our results show that stereomotion scotomas are the result of a failure to combine velocity signals from the two eyes. Further, we find that the inability to discriminate direction of motion through depth is reflected in the responses in early visual cortex. Since this visual deficit is the result of a cortical impairment and basic visual functions are intact, we conclude that the inability to discriminate the direction of motion in depth, should be considered a novel type of visual agnosia, namely a motion agnosia.

33.3043 **Using dichoptic moving-window presentation techniques to investigate binocular advantages during reading** Mirela Nikolova[1](M.Nikolova@soton.ac.uk), Stephanie Jainta[2], Hazel Blythe[1], Simon Liversedge[1]; [1]University of Southampton, Southampton, UK, [2]IfaDo - Leibniz Research Centre for Working Environment and Human Factors, Dortmund, Germany

Previous research indicates that binocular visual presentation results in superior reading performance. However, it is not entirely clear whether this is due to facilitated encoding of foveal or parafoveal information, or what amount of binocular visual input is necessary in order for binocular advantages during reading to occur. In a set of two experiments, we used a novel, dichoptic binocular gaze-contingent moving window technique to selectively manipulate the amount of binocular information available on a fixation-by-fixation basis during reading. In Experiment 1, sentences were presented with monocular input either exclusively in the fovea or in the parafovea. In Experiment 2, we further varied the amount of binocular visual information available in the parafovea to the right of fixation in order to quantify the amount of parafoveal binocular text necessary for uninterrupted reading. Results from Experiment 1 showed that monocular presentation of parafoveal text to the right of fixation was as disruptive to reading as monocular presentation of the entire sentence, even when foveal text was binocular. Experiment 2 demonstrated that this disruption could be reliably counteracted if at least one word in the parafovea to the right of fixation was also binocular. Interestingly, even though parafoveal monocular viewing conditions impaired reading performance in both experiments, binocular coordination processes (i.e. vergence movements) were efficient in all dichoptic presentation conditions. Furthermore, if only foveal input was monocular, fixation disparity was indistinguishable from the binocular reading condition. This implies a degree of dissociation between binocular coordination and reading performance in conditions of reduced binocular visual quality. Implications of the findings for binocular saccadic targeting will be discussed. The experiments demonstrate the importance of a unified, binocular input for the pre-processing of text to the right of fixation and underline the complex interplay between visual and cognitive processes during reading.

33.3044 **Without informative cues, little can be learned to discriminate eye of origin of visual inputs after multiple weeks of training** Li Zhaoping [1](z.li@ucl.ac.uk), Zihao Xiao[2]; [1]Department of Computer Science, University College London, [2]Department of Computer Science, Tsinghua University

Humans cannot discriminate eye of origin of visual input, when the informative cues such as feeling-in-the-eye are made uninformative (Ono and Barbeito, 1985), nor can they improve discrimination by one week of daily practice with feedback (Blake and Cormack, 1979). We ask whether improvement is possible by more extensive training (Zhaoping and Xiao 2015). The two authors practiced this task with feedback for multiple weeks, with occasional holiday breaks. Typically, each trial presented the observer a brief (200 ms) dichoptic test stimulus containing an array of monocular items. The observer had to report the ocular origin of the central target item, which was distinctively shaped from the other, task-irrelevant, non-target items. The ocular origin and the luminance of all the monocular items were randomly and independently assigned, and the non-target items in the two eyes were bars tilted in opposite directions from vertical. Binocular dots between monocular items were used to anchor vergence. This test stimulus was preceeded by binocular fixation stimulus and followed by a binocular mask. A random third of the trials were control trials containing no target item, prompting for a distinct response. In initial days, the target was a vertical bar. After 14-20 training days, the task performance (for non-control trials) rose consistently above the chance level to contain correct responses in 70-80% of the trials. One observer noticed, on her 31st training day, that the apparent tilt of the target was informative since it correlated with its ocular origin, perhaps caused by her astigmatism. Modifying the stimulus design to remove each confirmed or suspected informative cue often immediately dropped performance, and further training on the modified design often raised performance, revealing additional informative cues, which were then further removed. Eventually, performance could not be improved beyond 55% correct by more than two weeks of training.

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33.3045 **Unconscious affective feedback modulates behavioral choice** Xiulling Zhang[1](journeyonstars@126.com), Xue Zhang[2], Qiyang Nie[3], Sheng He[4], Jing Luo[5], Yi Jiang[2]; [1]School of Psychology, Northeast Normal University, China, [2]Institute of Psychology, CAS, China, [3]Department of Psychology, Ludwig-Maximilians-Universität München, [4]Department of Psychology, University of Minnesota, [5]Department of Psychology, Capital Normal University, China

One's behavioral choice is usually based on many external and internal factors which he or she may not be all aware of. Recent studies have shown that certain subliminal visual information, especially that with strong emotional connotation, can still be processed and even influence our spatial attention. The current study further queries whether behavioral choice can be modulated by the consequence of the choice at a level below conscious awareness. We show that subjects' choices of two otherwise equivalent items are significantly influenced by the invisible interocularly suppressed feedbacks following their choices, so that overall they tend to select the item followed by appealing feedback and

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avoid the item followed by aversive feedback despite they are unaware of the nature of the feedbacks. Our findings demonstrate that humans can optimize their behavior without conscious cost-benefit calculation.

33.3046 **Eyes Still Off the Prize: Impact of Visual Discomfort in College Population** Alison Hochman[1](alison.hochman.943@my.csun.edu), Jasmine Awad[1], Taravat Gorji[1], Daniel Larranaga[1], Stefanie Drew[1]; [1]California State University, Northridge

Introduction. Visual discomfort is a common condition associated with performing near work tasks such as reading or viewing computer screens. Symptoms can include headaches, eye strain, double vision, blurred vision, and sensitivity to light. Two ocular systems contribute to near work performance: the accommodative system, in which the lens of the eye thickens to keep a target in focus, and the vergence system, involving the coordination of the two eyes to keep a target centered on the retina. Disorders of both of these systems have been found to be associated with visual discomfort symptoms. The Conlon Visual Discomfort Survey (VDS) has been found to reliably be associated with accommodative insufficiency while the Convergence Insufficiency Symptom Survey (CISS) has similarly been found to be associated with convergence insufficiency. Given the high degree of near work associated with student success, the prevalence of visual discomfort in the college population is of great interest and relevance. Methods. We administered the VDS and CISS as well as an assessment of Grit, one's ability to persevere and overcome challenges. Survey results were then examined in terms of association with student academic performance and hours dedicated to near work tasks. Results. A large sample of undergraduate students participated in this study. More than 40% of participants fell into the high symptom category for the VDS, and more than 65% of participants fell into the high symptom category for the CISS. Significant correlations were observed between VDS symptom scores, grit, and cumulative GPA. Discussion: These preliminary data suggest a high prevalence of visual discomfort in the university population, with a significant impact on academic performance. Subsequent multiple regression analysis revealed both VDS and CISS significantly account for a portion of the variance in GPA.

Motion: Interactions with motion processing

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4001 **Response-related differences in the biases of perceived motion direction** Elisa Zamboni[1](lpxez@nottingham.ac.uk), Timothy Ledgeway[1], Paul McGraw[1], Denis Schluppeck[1]; [1]School of Psychology, University of Nottingham

Following a fine direction-discrimination task, subjective reports of the motion direction can be systematically biased away from an oriented reference line. A decoding model that preferentially weights the responses of mechanisms tuned to directions away from the decision boundary can quantitatively account for such repulsion effects (Jazayeri & Movshon, 2007). However, an alternative possibility is that this repulsion effect is due to a bias in subjects' responses. We investigated this by manipulating two aspects of a global motion discrimination task: (1) the presence of a reference line and (2) the modality used to obtain reports of motion direction. In the first experiment, subjects performed a fine-discrimination task while a reference line was present. Subsequently, they estimated the perceived direction of motion by manually adjusting the orientation of a test line either in the presence or absence of the reference. When the reference was present during the estimation phase, reports of motion direction were systematically biased away from the reference. Importantly the same pattern of responding was found even when subjects were not asked to perform the initial fine-discrimination task. Furthermore, when subjects estimated motion direction in the absence of the reference line, their responses were veridical. In a second experiment, subjects reported the perceived direction of motion in the presence of a reference line by making a saccade. Surprisingly, under these conditions, repulsion from the reference line was greatly reduced. These findings are hard to reconcile with the idea of weighted decoding. As the repulsion effect depends on the presence of an explicit reference when a manual adjustment task is used, it most likely reflects a task-dependent bias in the subjects' responses.

33.4002 **Motion shifts number-line location** Leslie Welch[1](leslie_welch@brown.edu), Chloe Kliman-Silver[2]; [1]CLPS, Brown University, [2]Computer Science, Brown University

Introduction: Studies on mental arithmetic show that location on the number line can be malleable such that addition causes location biases to the right and subtraction to the left (Pinhas & Fischer, 2008). Motion can cause illusory shifts in location (eg Ramachandran & Anstis, 1990) so we wondered if motion could shift location on the number line. Method: Participants viewed displays of a single-digit number at fixation with moving-dot patterns in the background. The primary, timed task was to categorize numbers as < 5 (digits 2,3,4), =5, or >5 (6,7,8). Half of the trials had target 5 to reduce the response time to that target; this also caused target 5 to be treated as a spatial anchor that could be compared to the other numbers. Response times tend to be slower to numbers close to category boundaries compared with numbers farther away (Dehaene, 1997) so we used RT as a measure of distance to boundaries. In the display background, 25%-coherent moving dots were shown traveling rightward or leftward, randomly from trial to trial. A secondary, untimed task was to indicate the direction of the background motion, right or left. Results: Reaction times for target 4 were slower with rightward background motion suggesting the motion shifted 4 to the right, closer to the category border with target 5. RTs for target 6 were faster with rightward motion suggesting that 6 was also shifted to the right and farther from target 5. Leftward background motion had the opposite effect. Conclusion: Background motion caused number categorization RTs to be asymmetric, depending on the motion direction. Motion shifted apparent distances between anchor target 5 and other digits.

33.4003 **Video Quality Assessment Using Motion Silencing** Lark Kwon Choi[1,2](larkkwonchoi@gmail.com), Alan Bovik[1,2]; [1]Department of Electrical and Computer Engineering, The University of Texas at Austin, [2]Center for Perceptual Systems, The University of Texas at Austin

Salient luminance (or color, etc.) changes in stimulus are imperceptible in the presence of large, coherent object motions (Suchow and Alvarez, 2011). From a series of human subjective studies, we found that this now well-known "motion silencing" phenomenon also happens on naturalistic videos, where large motion strongly suppresses flicker visibility (Choi et al, 2015). Based on these visual change silencing effects, we have developed a new video quality assessment (VQA) model that accounts for temporal flicker masking on distorted natural videos. We have developed a flicker sensitive motion-tuned VQA framework that first linearly decomposes reference and test videos using a multiscale spatiotemporal 3D Gabor filter bank. The outputs of quadrature pairs of linear Gabor filters are squared and summed to measure motion energy. These responses are then divisively normalized to represent the nonlinearity of adaptive gain control of V1 complex cells. We capture perceptual flicker visibility by measuring locally shifted response deviations relative to those on the reference video at each subband, then define the sum of deviations as a perceptual flicker visibility index. Spatial video quality is predicted using spatial errors from each subband Gabor response and the DC subband Gaussian filter output using divisive normalization. To measure perceptual temporal video quality, flicker visibility is combined with motion-tuned space-time distortion measurement that relies on a model of motion processing in Area MT (Seshadrinathan and Bovik, 2010). Results show that the video quality predicted by the proposed VQA model correlates quite well with human subjective judgments of quality on distorted videos, and its performance is highly competitive with, and indeed exceeds, that of most recent VQA algorithms tested on the LIVE VQA database. We believe that perceptual temporal flicker masking as a form of temporal visual masking will play an increasingly important role in modern models of objective VQA.

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33.4004 **The "Bendy Bars" Illusion: Shape deformation of dynamically occluded stationary columns due to misbinding of motion signals.** Gennadiy Gurariy[1](genaxl@yahoo.com), Gideon Caplovitz[1]; [1]University of Nevada, Reno

We introduce a novel illusion – the Bendy Bars illusion, in which stationary bars (i.e. a vertical sinewave grating) appear to bend when dynamically occluded by translating Gaussian ovals. This effect, however, only becomes visible once specific parameters have been met: The illusion is strongest when there are multiple vertically elongated ovals drifting horizontally back and forth across the bars and the relationship concerning spatial frequency and distance between each oval should be such that would allow visibility of individual bars in-between the moving elements. Furthermore, the effect appears to be strongest at lower speeds, also likely due to visibility issues. Why does the illusion occur? As the occluding Gaussians move back and forth there is ambiguity as to which object: the occluders or the bars, the corresponding motion energy belongs to. Although the exact rela-

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tionship between the motion signals present in the stimulus and the illusory deformation seen in the background remains to be elucidated, we hypothesize that the illusion arises due to a misbinding of motion signals whereby some of the motion energy from the drifting ovals is misattributed to the bars causing the illusion of a global bending in the direction of motion.

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33.4005 **Moral Psychophysics** Julian De Freitas[1](defreitas@g.harvard.edu), George Alvarez[1]; [1]Department of Psychology, Harvard University

In a typical Michotte billiard ball display, one ball moves and then stops next to a second ball, which then moves. In such displays, people can't help but see the first ball causally launch the second. In an analogous fashion, certain types of object motion (e.g. 'chasing', stopping and starting) irresistibly induce the perception of animacy (Scholl & Tremoulet 2000, Trends in Cognitive Sciences). Here we investigate whether perceived causality and animacy influence moral intuitions (blame, moral character). Participants saw two objects move around in an animate, self-propelled manner, then stop some distance apart. Next, the objects interacted either causally (e.g., launching), or non-causally (e.g. the second object moved before the first could hit it). In all conditions, the second object then happened to get trapped inside a container and 'tried to get out'. We reasoned that the first object should appear responsible for this negative outcome after a causal interaction, but less so after a non-causal interaction, during which the second object should appear to move intentionally rather than against its will. We found that moral judgments varied across 7 different object interactions (N = 375 between-subject design, $p < .001$), and these judgments correlated with intentionality ratings for the second object ($R2 = 0.82$, $p = .004$). When the objects interacted without initially moving animately then moral judgments were less severe (N = 919, $p < .001$), yet the basic pattern of moral judgments across conditions was similar for inanimate and animate trials ($p = .412$). We also found similar effects when participants read a verbal narrative (typical of moral psychology studies) accompanied by real-world objects interacting causally vs. non-causally (N = 194, $p = .033$). Thus, basic principles of perception can influence social judgments, stretching current notions of what vision is 'for'.

33.4006 **Attention is necessary for flicker-induced hallucinations** Yeseul Kim[1](yeseul0408@gmail.com), Chai-Youn Kim[1], Joel Pearson[2]; [1]Department of Psychology, Korea University, [2]School of Psychology, University of New South Wales

Hallucinations are generally defined as an awake, percept-like experience in the absence of the appropriate causative stimulus. One hypothesis is that differential processing in high-level attentional networks produce pathological hallucinations (Shine et al., 2011; Shine et al., 2014), accordingly attentional deployment should alter hallucination processing. To test this we utilized luminance flicker to induce visual hallucinations (Billock & Tsou, 2007) and removed endogenous attention from the flicker-induced hallucination. A white annulus flickering at 8Hz on a black background induced reliable hallucinated content (blobs) that rotated around the annulus. We utilized prior perceptual motion to induce an after-effect in the hallucinated motion, as a means of controlling it. There were 3 conditions, inattention, attention and no stimulus, immediately following the perceptual adaptation motion stimulus. In the inattention condition, a central fixation point was replaced with a rapidly changing letter stream (RSVP), while the annulus continued to flicker. Participants were instructed to count the number of the target letters and report it at the end of the trial. In the attention condition, visual presentation was identical to the inattention condition, but participants were asked to pay attention to annulus and report the perceived rotation direction of the flicker induced hallucination, ignoring the RSVP letter stream. In the no stimulus condition, only the fixation point was presented. Finally post-manipulation, the flickering annulus was presented again and subjects reported their hallucinated motion percept. We analyzed the degree of congruence between the perceived direction in final stimulus with the initial perceptual stimulus. Results showed a significant difference between the attention and inattention conditions, while congruence between inattention and the no stimulus was comparable. These data suggest that disregarding a flicker induced hallucination is equivalent to having it removed from view. Thus, inattention abolishes flicker induced hallucination, supporting the role of top-down attention in hallucination formation.

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33.4007 **Using internet search engines to probe for human perceptual biases: Preferences for object poses in time** Thomas Langlois[1](thomas.langlois@berkeley.edu), Alexei Efros[1]; [1]University of California, Berkeley

Human preferences for canonical viewpoints of objects are a well-known and much studied perceptual phenomenon. Recent work using computational methods from machine learning and computer vision has revealed that canonical viewpoints are the most common views returned by internet search engines for a wide variety of object categories. Using thousands of images returned by search engines has made it possible for prevailing psychological theories on canonical viewpoints to be challenged and refined (Mezuman & Weiss, 2012). In this work, we show experimental evidence for a new perceptual phenomenon: preferences for poses of dynamic objects in time. In the same way people have preferences for some viewpoints of objects over others in the spatial domain, we show that people have preferences for poses of dynamic objects over time. In addition, we show evidence that images returned by search engines correspond to human preferences for poses in time, suggesting that human perceptual biases can be uncovered from large online image databases. In particular, the frequency distribution of particular poses in photographic sequences of dynamic objects (such as sequences of a horse in motion, or an athlete throwing a ball) is positively correlated with ratings of the poses in the photographic sequence. In other words, preferred poses in the photographic sequence also tend to be more frequent in images returned by internet search engines when queried for images of a given dynamic object (i.e. a galloping horse, or a pitcher throwing a ball).

Perception and Action: Grasping and tracking

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4008 **Conscious perception and grasping rely on a shared depth encoding** Carlo Campagnoli[1](carlo_campagnoli@brown.edu), Fulvio Domini[1,2]; [1]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [2]Center for Neuroscience and Cognitive Systems@UniTn, Italian Institute of Technology

Accurate estimation of object depth is widely believed to underlie the successful execution of grasping movements. Specifically, it has been proposed that retinal disparities play a critical role in grip pre-shaping and stable finger placement on the object surface, under the assumption that stereo information produces veridical depth estimates. If this were the case, then grasp kinematics should be accurately attuned to the veridical 3D structure of objects. Moreover, they should not be affected by the systematic biases that are known to distort perceptual judgements of object depth. Here we tested these predictions by presenting participants with 3D virtual objects defined by various combinations of stereo, motion and texture information at two egocentric distances. In separate sessions, participants were asked to (a) manually estimate the perceived front-to-back extent of the targets or (b) naturally reach-to-grasp the targets. In the perceptual task, we found that stereo-only objects presented at the far distance (45 cm) appeared most shallow; perceptual depth increased (1) by bringing the objects closer to the observer (30 cm) and (2) by adding either motion or texture information to the baseline stereo objects. These findings are consistent with the idea that visual space is compressed and also that depth estimation is non-veridical. Remarkably, the results of the grasping task revealed that the anticipatory opening of the hand followed the same patterns as the manual depth estimates – the grip aperture was smallest when grasping the distant, stereo-only objects and largest when grasping near, multiple-cue objects. These findings show that visual processing of shape for action control shares the same intrinsic biases known to influence depth perception, providing further evidence for common coding of object properties for perception and action.

33.4009 **Manual estimation: Feedback affects bias but not precision** Karl Kopiske[1,2](karl.kopiske@gmail.com), Alexander Gornik[2], Volker Franz[2,3]; [1]Active Vision Lab, Center for Neuroscience and Cognitive Systems, Istituto Italiano di Tecnologia, [2]Department of General Psychology, University of Hamburg, [3]Department of Experimental Cognitive Sciences, University of Tübingen

Manual estimation (ME) is frequently used to assess human processing of visual size information. Since the required actions are very similar to grasping, ME and grasping are often compared. The main difference between ME and grasping is the goal of the action (indicating a size with two digits vs. picking up an object) and the feedback participants receive (no direct feedback vs. haptic feedback on whether a comfortable grip was achieved). Surprisingly, the influence of feedback on ME is not very well known. We investigated whether feedback affects accuracy and precision in ME at all. N=33 participants performed ME tasks with varying feedback about whether the goal of the action was achieved. In two within-subject conditions, participants either viewed reference objects and indicated their sizes using index finger and thumb (visual-input condition; object sizes: 20, 60, and 100 mm), or indicated a freely-chosen size (no-visual-input condition). In both conditions, participants then reproduced their original estimate (which we will call 'reference estimate'), without any further visual input. First, participants repeated their estimates without any feedback, followed by a block with automated verbal feedback reflecting the accuracy of the estimate, followed by another block without feedback. Our main dependent variables were the accuracy (i.e., mean difference to the reference estimate) and the precision (i.e., standard deviation) of the estimates. We found systematic biases both in the visual-input and in the no-visual-input conditions. Biases were correlated with the reference estimate, as was estimation precision. These biases were greatly reduced by the verbal feedback but reappeared when verbal feedback was removed again, while precision was the same in verbal feedback and no-verbal feedback blocks. We conclude that systematic biases in ME depend on the magnitude of the ME response. Direct feedback can alleviate these biases, but does not calibrate ME lastingly or improve precision

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33.4010 Visual information about object size and object position are retained differently in the visual brain: Evidence from grasping studies. Constanze Hesse[1](c.hesse@abdn.ac.uk), Louisa Miller[1], Gavin Buckingham[2]; [1]School of Psychology, College of Life Sciences and Medicine, University of Aberdeen, [2]Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter

Many recent studies have focused on the question of whether or not visually-guided and memory-guided hand movements rely on dissociable visual representations that are processed in anatomically different brain areas (dorsal vs. ventral). However, little attention has been paid to the issue of which aspects of the visual information decay over time and how decay functions differ for relevant visual features. In three experiments, we investigated whether the representation of object position (guiding hand transport) decays more rapidly than the representation of object size (guiding grasp pre-shaping). Using a mirror setup, we dissociated information about object position and size. In Experiment 1, we presented objects at different distances to the observer. After varying pre-response delays that increased memory demands successively, participants pointed to the remembered object position. We found that distance errors increased exponentially with increasing memory demands, indicating that visual information about object position decays rapidly as soon as vision is occluded. In Experiment 2, we investigated grasping movements to differently sized objects while providing information about their position (using a landmark) in the same vision conditions. We found that grasp pre-shaping remained constant and well-adjusted to object size even after long delays, suggesting that object size is encoded in a relatively stable manner. This was confirmed in Experiment 3 in which we measured pre-liftoff fingertip force rates as an indicator of remembered object size that is unaffected by object position. Fingertip force rates were similar across all delay conditions, further highlighting the robustness of the object size representation. Our findings suggest that visual information about object positon and object size are stored independently, and that larger grip apertures typically seen in delayed grasping tasks are likely to reflect an increased uncertainty about object position rather than object size (larger safety margin compensating for increased reaching errors).

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33.4011 Weber's law in bimanual grasping and perceptual estimations Tzvi Ganel[1](tganel@bgu.ac.il), Gal Namdar[1]; [1]Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva, Israel

According to Weber's law, a fundamental principle of visual perception, the visual resolution for object size decreases in a linear fashion with an increase in size. Previous studies from our lab and from other labs have shown, however, that unlike perceptual estimations, that adhere to Weber's law, the resolution of grasping movements during single-handed grasping is not affected by the object's size and therefore does not adhere to Weber's law. Therefore, it has been argued that the control of action is not affected by the same psychophysical laws that affect perception. The purpose of the current study was to extend this proposal by looking at actions beyond single hand grasping, which also allows looking at a considerably wider range of stimulus size beyond that used in previous studies. To this purpose, we asked participants to grasp or to estimate the size of large objects using both their hands. The Just Noticeable Differences (JNDs) during movement trajectories served as a measure for the visual resolution to size. The results showed that similarly to unimanual grasps, bimanual grasps did not adhere to Weber's law. In contrast, JNDs for perceptual estimations of the same objects increased in a linear fashion with object size, in agreement with Weber's law. These findings indicate that unlike perception, the visual resolution of visuomotor control is absolute and does not depend on object size.

33.4012 The effects of magnitude on visually guided action and perception. Gal Namdar[1](namdargal@gmail.com), Tzvi Ganel[1]; [1]Department of Psychology, Ben-Gurion University of the Negev.

Recent research has established the role of objects' semantic properties in the planning of motor actions with respect to these objects. It has been shown that visual magnitude affects visuomotor control in a similar direction to the effect of physical size: Larger magnitudes lead to larger grip apertures during grasping, even when physical size remains invariant. Despite the growing literature regarding this effect, little evidence has been gathered as for the way magnitude processing affects the visual perception of object's size. To address this issue, we presented participants with different representations of magnitude across both the auditory and the visual modalities, while asking them to either grasp a neutral object (action), or perform manual estimation of the object's size (perception). In Experiment 1, longer durations of an auditory stimulus led to larger grasping apertures during grasping, while manual estimations were not affected by the presented stimulus duration. When numerical magnitude information was conveyed visually (Experiment 2), this distinction became less prominent. Overall, these results lend further support for the idea that a common mechanism mediates visuomotor control and the processing of magnitude across different domains.

33.4013 Moving Targets: Effects of Occlusion on Eye and Grasp Movements Ryan Langridge[1](langrirw@myumanitoba.ca), Jonathan Marotta[1]; [1]Department of Psychology, University of Manitoba

When interacting with our environment, visual information provided by objects we intend to grasp is not always consistent or readily available. This is especially true concerning moving objects, which have the potential to become occluded by larger, closer objects. This study involved participants making pantomimed grasps toward horizontally translating computer-generated targets that were either visible throughout the trial or appeared to move behind an occluding object during travel. The presence of additional computer generated blocks along the top and bottom of the screen was manipulated to test for an effect of increased allocentric information on visual pursuit and grasp accuracy. Eye movement and grasp kinematics were monitored. Results indicate that participants executed more accurately placed grasps and were better able to visually pursue the target with visual feedback than without. Smooth pursuit eye movements were achieved while the target was visible. Once the target encountered the occluder, fixation was maintained until complete occlusion, after which saccades were used to reproduce target movement. Gaze analysis indicated that participants were able to efficiently pursue occluded targets prior to being cued to execute the reach. However, when grasps were made towards occluded targets, the locations of the final gaze and index finger placement were significantly displaced from the target's horizontal position, suggesting that position error occurs during the reach. Surprisingly, the presence of additional cues appeared to have minimal influence on gaze or grasp accuracy, and even impaired accuracy for rightward moving occluded targets. Additionally, cue presence was associated with a gaze position closer to the top edge of the target at the time of grasp. These results indicate impaired performance when visually pursuing and grasping for occluded targets, and specifically highlight the reach component as contributing to position error. Further research is required to understand what differentiates a 'cue' from a 'distractor.'

Acknowledgement: NSERC Discovery Grant

33.4014 Affordance perception in socially contracted peripersonal space Elizabeth Saccone[1](elizabeth.saccone@flinders.edu.au), Owen Churches[1], Ancret Szpak[1], Michael Nicholls[1]; [1]School of Psychology, Flinders University of South Australia

Humans are highly skilled at perceiving manipulable objects and performing action toward them. To account for such precise coordination of vision and action, object affordance research suggests attending to an object activates relevant motor programs, and this may be particularly the case for objects in peripersonal or reachable space. Peripersonal space boundaries are flexible, however, and proximity of another person can contract this boundary because it overlaps with preferred social distance. Whether socially contracted peripersonal space influences object affordance perception is currently unknown but was investigated in the current study. Participants stood on one side of a narrow table and viewed object stimuli presented in reachable space on a screen that lay flat. Participants responded to the upright or inverted orientation of objects that had handles facing left or right. Social condition varied within subjects, such that participants performed the task both alone and together with a confederate standing on the other side of the table. Objects appeared in one of two locations, either closer to the participant's side of the table or nearer the confederate's. The typical affordance effect emerged in that there was a response advantage when left/right response hand matched the object's left/right handle orientation. When participants performed the task with the confederate, however, the affordance effect was only present for objects closer to the participant. When the task was performed alone, the affordance effect was found for objects in both locations. These results suggest that social proximity affects the perception of object affordances owing to contracted or shared peripersonal space. This study adds to the growing literature of how well-documented cognitive phenomena are influenced by social presence and therefore, how they might apply in a real world context.

33.4015 **A Double Dissociation Between Perception and Action Using Sander's Parallelogram: Demand Characteristics Come Up Short** Robert Whitwell[1], Sina Safabakhsh[1], Carmen Wong[1], James Enns[1]; [1]Department of Psychology, The University of British Columbia

According to the Interface Theory of Perception, perceptual representations reflect evolutionary entrainment to utility rather than reality. In contrast to perception, object-directed action involves physical interaction which can be harmful or beneficial to the agent. Thus, actions need to be accurate and the representations that underlie them need to be veridical. Arguably, utility and physical reality are perfectly aligned for action. Consistent with this view, a number of studies have shown that object-directed actions resist pictorial illusions. Nevertheless, this work has largely ignored the fact that one's belief about the properties of a stimulus can contradict moment-to-moment visual experience. It is therefore possible that actions resist illusions because they are guided by veridical beliefs whereas perceptual estimations are guided by 'fooled' visual experience. In short, demand characteristics might be responsible for dissociating action and perception. Here, we tested this possibility directly. We asked participants to manually estimate the length of different 3D-target bars embedded in Sander's Parallelogram illusion or to reach out and pick them up. Critically, we positioned the bars such that the physically-shorter ones could appear longer than their physically-longer counterparts. This arrangement served a dual role, pitting perception and action against one another while reducing demand characteristics; pictorial displays that can reverse the apparent difference in target length are rarer than the more 'traditional' displays which induce an apparent difference in target length when no difference exists. The results revealed a double dissociation: grasps reflected the real difference in target length whereas manual estimates reflected the illusory difference. At the end of the study, participants were asked whether or not they believed the targets differed in physical length. A large majority affirmed a difference existed, indicating that the difference was in the direction of the illusion. Thus, demand characteristics based on belief cannot explain the perception-action dissociation.

33.4016 **Similar effects of visual context dynamics on eye and hand movements** Philipp Kreyenmeier[1](philipp.kreyenmeier@googlemail.com), Jolande Fooken[1,2], Miriam Spering[1,2,3,4]; [1]Ophthalmology & Visual Sciences, University of British Columbia, [2]Graduate Program in Neuroscience, University of British Columbia, [3]Center for Brain Health, University of British Columbia, [4]Institute for Computing, Information and Cognitive Systems, University of British Columbia

The perception of visual motion and the ability to track a moving target with smooth pursuit eye movements are strongly context-dependent. Despite similar processing mechanisms and pathways, visual contexts can have opposite effects on perception and pursuit (Spering & Gegenfurtner 2007; 2008): context motion in a particular direction can speed up perception but slow down pursuit, and vice versa. By contrast, here we show that visual contexts have similar effects on pursuit and hand movements. Observers (n=11) tracked a target moving across a screen and hit it with their index finger after it had entered a "hit zone". Following brief presentation (100-300 ms) along a curved trajectory, observers had to extrapolate and intercept the target at its assumed position; feedback about actual position was given after interception. The target was either presented on a uniform grey background or on a naturalistic texture (motion cloud; Leon, Vanzetta, Masson & Perrinet, 2012), which was either static or moved in the same direction and at the same mean speed as the target. We analysed background effects on the accuracy and dynamics of tracking and interception movements. Static backgrounds significantly slowed pursuit (longer latency, lower acceleration and velocity gain) and dynamic backgrounds speeded pursuit (shorter latency, higher acceleration and gain), both in response to the visible and the invisible target trajectory. Effects of similar direction and magnitude were observed for hand movement dynamics (latency). Interestingly, position errors in eye and hand (interception accuracy) were lower for static than for dynamic backgrounds, where observers' estimates of target position overshot actual end position. Similar effects of context dynamics on eye and hand movements suggest that the eye- and hand-movement systems may rely on similar sources of information for visual-motor prediction tasks.

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33.4017 **Action videogame play improves eye-hand coordination** Rongrong Chen[1](rainerrchen@hku.hk), Li Li[1,2]; [1]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR, [2]Neural Science Program, NYU Shanghai, Shanghai, PRC

We recently found that action videogame play enhances visuomotor control and the coupling between pursuit eye movements and visuomotor control. Here we examined whether action videogame play improves eye-hand coordination. We tested 13 action gamers and 13 gender-matched non-gamers with an oculo-manual control task which consisted of two conditions. In the eye-hand condition, the display (40°Hx30°V) presented pseudorandom movement of a cyan Gaussian target (σ=0.6°) whose horizontal position was perturbed by the sum of seven harmonically-unrelated sinusoids (0.1–2.19 Hz). Participants were instructed to smoothly track the target with their eyes while using their dominant hands to move a high-precision mouse to vertically align a red Gaussian cursor (8° below) with the cyan target. In the eye-alone condition, the display replayed the target and cursor positions recorded in the eye-hand condition and participants were instructed to only track the target with their eyes. Action gamers and non-gamers did not differ in their eye-tracking performance in the eye-alone condition. However, in the eye-hand condition, action gamers showed better tracking precision (measured as the RMS error), larger response amplitude (gain), and shorter response lag (phase) for both eye and hand tracking than did non-gamers. Consistent with our previous findings that concurrent hand tracking enhances pursuit eye movements, both groups made a smaller number of saccades in the eye-hand than in the eye-alone condition. While action gamers also showed a larger smooth pursuit gain (mean ± SE: 16.2% ± 3.6% larger), non-gamers showed a smaller smooth pursuit response delay (16.5% ± 7.4% smaller) in the eye-hand than in the eye-alone condition. Our findings provide the first empirical evidence on that action videogame play improves eye-hand coordination when tracking an unpredictable moving target.

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33.4018 **"There's something about offsets": Offset events cannot be associated with reaching movements** Emma Yoxon[1](emma.yoxon@mail.utoronto.ca), Meera Sunny[2], Timothy Welsh[1]; [1]Centre for Motor Control, Faculty of Kinesiology and Physical Education, University of Toronto, [2]Indian Institute of Technology Gandhinagar

The present experiment integrates two lines of research regarding action and the salience of stimuli for action. The first line provides evidence that attentional capture can be modulated by how the stimuli relate to the action being performed. Onset events (appearance of a new object) are salient for reaching movements. Conversely, offset events (disappearance of an object) are not salient for reaching movements because they do not afford a location-specific response. In support of the hypothesized salience of each event, onset distractors have been shown to capture attention and cause interference during aiming movements whereas offset distractors do not. The second line of research involves ideomotor theory. According to ideomotor theory, the neural codes for actions are closely bound to the neural codes for the perceptual effects of those actions. Associations between actions and effects are built through experience with a given action-effect pairing. Importantly, learned action-effect pairings have been shown to modulate attentional capture (Kumar, Manjaly & Sunny, 2015). The current experiment examined whether an association could be developed between reaching movements and offset events. Participants performed a free-choice reaching task before and after an acquisition phase. In the pre/post-test phases, participants reached towards one of three target placeholders after the disappearance of a target in one of those placeholders. In the acquisition phase, participants reached towards targets that would disappear when contacted. It was hypothesized that this action-effect experience would lead to a coupling between reaching movements and offset events, thereby increasing the salience (and the propensity for attentional capture) of the offset event. It was found, however, that the frequency with which participants moved towards a placeholder that held the offset event did not significantly differ from the pre-test to the post-test. Therefore, the data suggest that participants were unable to associate reaching movements with offset events.

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Multisensory Processing: Vision, speech and music

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4019 Gradual consolidation of synesthesia during adolescence: a case study

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Synesthesia is a rare condition in the normal observer where an inducer quale is consistently followed by a second, concurrent quale (Grossenbacher & Lovelace, 2001). Several studies have demonstrated the effects of synesthesia through a number of objective measures; like visual search (Laeng, 2009), visual priming (Mattingley, Rich, Yelland, & Bradshaw, 2001), and the Stroop task (Mills, Boteler, & Oliver, 1999). In a recent study Ásgeirsson, Nordfang, & Sørensen (2015) isolated specific components of attention that are modulated by synesthesia, and which seem to correspond to attentional changes modulated by expertise (Sørensen & Kyllingsbæk, 2012; Dall, Watanabe, & Sørensen, in review). Here we explore a case of a young female synesthete; AR (age 13), who presented an unusual, but consistent, color profile that allowed us to explore the effects of partial color encoding in synesthesia. Interestingly, we were not able to reproduce the attentional modulations reported by Ásgeirsson et al. (2015) as AR did not show any convincing modulation of known attentional parameters. Several studies have demonstrated that synesthesia can be acquired during childhood (e.g. Witthoft & Weaver, 2006), and recently Simner & Bain (2013) has convincingly shown that consolidation of colour-grapheme synaesthesia develop during childhood and early adolescence. Together these studies seem to suggest that the attentional effects seen in adult observers who have colour-grapheme synaesthesia may in fact reflect an expertise related modulation between long-term colour-grapheme associations. To explore this hypothesis a follow-up screening of AR's colour-grapheme associations revealed that a number of letters are still settling on their final colour association – colour changes that AR herself was unaware of, e.g. that L had changed from red to blue. Additionally, AR's overall consistency also markedly increased over the ~2 year between the screening sessions, similar to results reported by Simner & Bain (2013).

33.4020 The Stolen Voice Illusion

David Brang[1](dbrang@gmail.com), Satoru Suzuki[1], Marcia Grabowecky[1]; [1]Department of Psychology, Northwestern University

Auditory speech is typically accompanied by related visual cues that enhance speech perception and compensate for degraded auditory processing due to environmental noise or auditory deficits. This crossmodal enhancement is partly due to lip articulations crossmodally providing redundant contextual information to facilitate phoneme identification. However, past research has also demonstrated effects of face identity information, such that speech perception is impaired if lip articulations from one individual are presented simultaneously with the voice of another individual. We present a novel multisensory illusion (The Stolen Voice Illusion) that demonstrates that visual identity information can override the strong temporal cues that would normally indicate which voice is associated with which face. A female face and a male face articulating the same phoneme (e.g., /ba/) are presented side-by-side on the screen along with their voices. Critically, each voice is synchronized with the face of the incorrect gender: a female voice synchronized with male lip movements and male voice synchronized with female lip movements. One might expect that when the male-face/female-voice pair and the female-face/male-voice pair are presented asynchronously, temporal binding would make each face appear to speak with a voice of the opposite gender. Surprisingly, when the male-face/female-voice pair is presented gradually earlier than the female-face/male-voice pair, each voice is (incorrectly) perceived to originate from the matched-gender face up to about 500 ms of temporal asynchrony, as if the female voice migrated forward in time to bind with the later female face while the male voice migrated backward in time to bind with the earlier male face. When the interval is increased beyond the critical duration, the face-voice discrepancy abruptly becomes apparent. This novel illusion demonstrates the strong impact of visual identity on auditory speech perception, capable of overriding strong temporal cues that would otherwise indicate which voice was associated with which face.

Acknowledgement: This study was supported by NIH Grant K99 DC013828

33.4021 Re-Inventing Reading: Rapid multi-channel processing of language accelerates reading.

Matthew Schneps[1,2,3](mschneps@umb.edu), Chen Chen[3], Marc Pomplun[1], Jiahui Wang[4], Anne Crosby[3], Kevin Kent[3]; [1]Computer Science, University of Massachusetts Boston, [2]Sheller Teacher Education Program, MIT, [3]Havard Graduate School of Education, [4]University of Florida Gainesville

The prevailing methods used for reading have been honed through centuries of social engineering so as to be extraordinarily efficient. And yet most people read at speeds far below the known neurological limits for language processing (Vagharchakian, Dehaene-Lambertz, Pallier, & Dehaene, 2012, J. Neurosci.), using methods inherited from pen and ink technologies that are fast becoming obsolete. In this study we investigate whether the neurological cap on the speed of reading can be relaxed by invoking parallel multimodal pathways for language using concurrent visual and auditory presentations of text. Here, 40 college students with and without dyslexia used software that forcibly accelerated the visual presentation of text, which was concurrently rendered in tandem using compressed auditory text-to-speech. Observing speed and comprehension, we found that reading using this accelerated multimodal presentation was superior to reading accelerated text using either modality separately, controlling for comprehension. Importantly, when accelerated reading methods were compared with traditional methods of reading on paper, the traditional paper-based approach was found to be the least effective overall. The accelerated methods were also effective as an assistive technology: people with dyslexia read faster using multimodal accelerated methods when compared with typical readers using paper. Findings here suggest that in future evolutions — using technologies readily available today— parallel pathways for reading can be exploited to optimize reading, to make reading substantially more efficient and inclusive than possible using traditional paper-based methods

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33.4022 Silent lip reading generates speech signals in auditory cortex

L. Jacob Zweig[1](jacob.zweig@gmail.com), Marcia Grabowecky[1,2], Satoru Suzuki[1,2], Vernon Towle[3], James Tao[3], Shasha Wu[3], David Brang[1,2,3]; [1]Department of Psychology, Northwestern University, [2]Interdepartmental Neuroscience Program, Northwestern University, [3]Department of Neurology, University of Chicago

Visual lip movements improve auditory speech perception in noisy environments (e.g., McGettigan et al., 2012) and crossmodally activate auditory cortex (e.g., Pekkola et al., 2005). What specific information about visual lip movements is relayed to auditory cortex? We investigated this question by recording electrcorticographic (ECoG) activity from electrodes implanted within primary/secondary auditory cortex of the brains of epilepsy patients. We presented four representative auditory phonemes (/ba/, /da/, /ta/, and /tha/), or presented the corresponding lip movements, visemes, articulating these phonemes. We constructed an ensemble of deep convolutional neural networks to determine whether the identity of the four phonemes (from auditory trials) and visemes (from visual trials) could be decoded from auditory cortical activity. Reliable decoding of viseme identity would provide evidence of coding of visual lip-movement information in auditory cortex. We first verified that auditory phoneme information was reliability decoded with high accuracy from auditory-evoked activity in auditory cortex. Critically, viseme information was also reliably decoded from visual-evoked activity in both the left and right auditory cortices, indicating that visemes generate phoneme-specific activity in auditory cortex in the absence of any sound. Furthermore, the classifier trained to identify visemes successfully decoded phonemes with comparable accuracy, indicating that the patterns of activity in auditory cortex evoked by visemes (from visual trials) were similar to those evoked by phonemes (from auditory trials). These results suggest that visual lip movements crossmodally activate auditory speech processing in a content-specific manner.

Sunday AM

33.4023 **Emotionally mediated crossmodal correspondence and human information processing** Joshua Peterson[1](jpeterson@berkeley.edu), Stephen Palmer[1]; [1]University of California, Berkeley

A variety of crossmodal correspondences (e.g., size/pitch associations) have been shown to influence human information processing, demonstrated by their effect on stimulus classification performance, multisensory integration/perception, and modulation of motion perception (Spence, 2011). Palmer et al. (2013) have recently identified a new class of crossmodal music-to-color correspondences that are mediated by emotion: people tend to choose colors as going best with music when both have similar emotional associations (e.g., "happy" colors go best with "happy" music) for a diverse range of musical genres. Lower level musical stimuli, including single-line melodies, two-note intervals, and instrumental timbres, paired with alternative visual stimuli such as textures and abstract art show analogous effects (Peterson et al., VSS-2015). We examined whether these emotionally mediated crossmodal correspondences also influence human information processing. We find that people are slower and less accurate at classifying the emotionality of visual stimuli (color and faces) when simultaneously presented auditory stimuli (timbres and intervals) are emotionally incongruent as opposed to emotionally congruent.

33.4024 **How vertical stripes affect recognition of Chinese characters** Ye Hur Cheong[1], Richard H.Y. So[1,2], Arnold Wilkins[3]; [1]Department of Industrial Engineering and Logistics Management, the Hong Kong University of Science and Technology, HK, [2]Division of Bio-medical Engineering, the Hong Kong University of Science and Technology, HK, [3]Department of Psychology, University of Essex, UK

Stripes have been known to cause visual stress (Wilkins and Evans, 2007). The occurrences of stripes in nature often signify the possibility of poison (e.g., venomous snake, centipede) (Cole and Wilkins, 2011). Most alphabets contain vertical stripes. English and German sentences with words containing more vertical stripes can increase the reading time (Wilkins et al., 2007; Jainta, Jaschinski and Wilkins, 2010). Will a similar effect occur in the reading of Chinese characters, which are logographic based? Two studies have been conducted to investigate how the presence of vertical stripes affects the recognition time of Chinese characters, and their preliminary data will be presented here. In the first experiment, 3000 commonly used Chinese characters were taken from a published database (Poon and Hong, 2003). The characters were sorted according to their age of acquisition, frequency of use, number of strokes (including vertical, horizontal and diagonal), level of difficulty and the presence of vertical stripes. The presence of vertical stripes was detected and coded automatically by a MatlabTM program modified from Wilkins et al., (-2007). These 3000 Chinese characters were categorized into three types; (i) characters with high occurrence of vertical stripes, (ii) characters with low occurrence of vertical stripes, (iii) intermediate characters (were not used in the experiment). Subjects were instructed to read aloud arrays of Chinese characters, which were grouped by the number of strokes and the character type. The preliminary results of first 7 subjects showed that characters with more vertical stripes took significantly longer time to recognize ($p< 0.05$). Gaze data were collected in the second experiment with similar procedure. Preliminary data indicated a strong positive correlation between binocular fixation time and recognition time, characters with more vertical stripes also took longer time to recognize. Possible relationships between binocular fixation time and vertical stripes will be presented.

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33.4025 **When Colors Spell Words: A Study on the Bidirectionality Effect in Synesthesia** Jeannette Buenrostro[1](Jeannette.buenrostro.813@my.csun.edu), Daniel Del Cid[1], Brandon Hackney[1], Jasmine Awad[1], Taravat Gorji[1], Stefanie Drew[1]; [1]California State University, Northridge

Introduction. Synesthesia is a mixture of senses in which one sense is automatically triggered by another stimulation sense. Studying the cases in grapheme-color synesthetes, it has historically been believed that stimulation was unidirectional; letters induce a sense of colors but colors do not induce a sense of letters. Recently, a few studies have suggested that colors provoke the inducement of numbers (Cohen & Henik, 2006) suggesting the possibility of bidirectional synesthetic percepts. Methods. Here we've examined the possibility of having a bidirectionality effect with letter graphemes. The subjects included in this study were three synesthetes with matched controls. The stimuli consisted of two sets of color patches in which the colors corresponded with the associated letter graphemes of each synesthete. The color patches were presented in two forms: one set created a word (e.i. having red associated with "U" and blue with "P" spelling the word "UP"), and a non-word (e.i. blue patch followed by a red patch spelling the word "PU"). The participants were presented with a series of forced-choice trials and instructed to select the color patches that represented a word. Results. Results revealed a pattern in which that synesthetes performed significantly different from chance, while control participants typically performed at chance, suggesting possible bidirectional synesthetic perception related with letter graphemes.

33.4026 **Are Synesthetic Perceptions a 2 Way Street?: A Study On The Bidirectionality of Grapheme-Color Synesthesia.** Daniel Del Cid[1,2](daniel.delcid.270@my.csun.edu), Jasmine Awad[1,2], Brandon Hackney[1,2], Jeannette Buenrostro[1,2], Stefanie Drew[1,2,]; [1]Cal-State University Northridge, [2]Vision Information Science at Northridge

Introduction: Synesthesia is a phenomena that is marked by multi-sensory perceptions. Grapheme-color synesthetes experience color perceptions induced by viewing achromatic graphemes (numbers and letters presented in black text). Typically, the perceptions of these synesthetes have been considered to be unidirectional experience, meaning that numbers and letters induced certain colors but colors do not induce a sense of numbers or letters. Methods: In this study, we sought to examine the potential for colors to induce a sense of numerical value. Stimuli consisted of sets of color patches that corresponded with photisms perceived by the synesthete. For example, for a synesthete that associates 2 with red and 3 with blue, a stimulus would consist of red/blue patches ("23") and blue/red patches ("32"). Synesthetes and age matched controls were then presented with a forced-choice task in which they were required to indicate which of the two sequences demonstrated the highest magnitude. Results: Results indicated that synesthetes performed significantly different from chance while controls typically performed at chance. This data supports the possibility of synesthesia having bidirectional percepts, with colors that can evoke a sense of numerical magnitude. These bidirectional percepts suggest the potential for bidirectional communication between the underlying cortical regions responsible for processing these features.

Acknowledgement: CSUN Psychology Department, Associated Student Union

33.4027 **Regularities in Grapheme-Color Synesthesia** Nathan Witthoft[1](witthoft@stanford.edu), David Eagleman[2], Jonathan Winawer[3]; [1]Department of Psychology, Stanford University, [2]Department of Neuroscience, Baylor College of Medicine, [3]Department of Psychology and Center for Neural Science, New York University

Neuroscientists have long been interested in the origin of synesthetic pairings. Though the choices made by individual synesthetes sometimes appear idiosyncratic, recent work on moderately sized samples (~10-200 subjects) has found that colors associated with letters reflect environmental influences such as color words, letter frequency, and alphabetical order. We analyzed the letter-color matches from a large sample of grapheme-color synesthetes (6588 subjects) from the database at www.synesthete.org, and report several systematic patterns. The set of all 160,000+ color matches across letters appears to sample from the color space in a biased way. Black, white, red, and yellow are strongly overrepresented, while cyan and magenta are almost never chosen. Whether this bias is mediated by linguistics, perception, or physiological constraints is not known. Consistent with prior work, we find strong tendencies for many letters to be associated with particular colors (A -> red), some of which can be interpreted as arising from environmental influences (Y -> yellow). However, color choices are largely independent across letters: knowing the color of one letter carries little information about the color of any other letter. One interpretation is that environmental influences which drive the letter-color matches are present across the population, but operate probabilistically, suggesting that learning is a ubiquitous influence on grapheme-color synesthesia. We also examined the role of visual statistics on the distance between letter-color matches. Consistent with previous reports, measures of ordinality and letter frequency predict color distances when data are averaged across subjects and letters. However, analyses which take into account both subject variation and the fact that color distances between letter pairs are not independent, show very small effect sizes. Our observations support the view that synesthetic pairings are far from random or idiosyncratic. The findings are also consistent with a widespread role of learning in color-grapheme synethesia.

33.4028 **Can a word sound sharp before you have seen it? Sound-shape mapping prior to conscious awareness** Po-Jang Hsieh[1](pojang.hsieh@duke-nus.edu.sg), Shao-Min Hung[1], Suzy Styles[2]; [1]Neuroscience and Behavioral Programs, Duke-NUS, [2]Division of Psychology, Nanyang Technological University

The bouba–kiki effect depicts a non-arbitrary mapping between specific shapes and non-words: an angular shape is more often named with a sharp sound like 'kiki', while a curved shape is more often matched to a blunter sound like 'bouba'. Previous studies have shown that similar sound-to-shape mappings could happen across different cultures and early in development, suggesting the mappings may be innate and possibly universal. However, it remains unclear what level of processing gives rise to these perceptions. Here we examined whether the congruency of a sound–shape stimulus could be processed prior to consciousness. In Experiment 1, we manipulated the congruency of the stimulus by presenting the non-word 'bubu' or 'kiki' with its correspondent or non-correspondent shape. In each trial, a non-word was combined with a shape and presented with continuous flash suppression. The results exhibited the "congruency effect": Congruent pairs broke suppression and reached conscious awareness faster. Furthermore, we tested whether the congruency effect depended on the sound-shape consistency or was simply a result of the visual similarity between the non-words and shapes. In Experiments 2a and 2b, we trained participants to pair up one of the unfamiliar letters taken from West African Vai Script with the 'bubu' or 'kiki' sound. The congruency of the letter-shape pair was determined by the training received prior to the main experiment. For instance, a letter paired up with the sound "kiki" was deemed to be congruent with the angular shape. Again, the "congruency effect" was obtained. Crucially, Experiments 2a and 2b showed that the congruency effect stemmed from the congruent relationship between the shape and the sound represented by the letter but not the shared visual characteristics. Taken together, our results suggest that sound-shape mapping can happen automatically, and sensory congruency facilitates the access to conscious awareness.

33.4029 Audiovisual association between consonants and colors in non-synesthetes Hyun-Woong Kim[1](khw173@korea.ac.kr), Hosung Nam[2], Chai-Youn Kim[1]; [1]Department of Psychology, Korea University, [2]Department of English Language and Literature, Korea University

Previous studies on synesthesia have suggested non-random association between sounds of linguistic units and colors (Asano & Yokosawa, 2011; 2012; Shin & Kim, 2014). The cross-modal association between speech sound and color has also been generalized to non-synesthetes based on results from color matching to auditorily presented vowels (Kim et al., VSS 2015; Mok et al., 2015; Moos et al., 2014). In the current study, we extended our previous work by examining the relationship between consonant sounds and colors. We employed 25 synthetic consonant-vowel (CV) sounds as stimuli generated by using Haskins laboratories articulatory synthesizer. In the stimulus set, the organ of constriction (lips, tongue tip, tongue body), constriction degree, glottal gestures, and velum gestures were parametrically manipulated with the vowel gesture fixed at its rest position. A total of 46 participants were tested with a modified version of the standardized color-matching procedure (Eagleman et al., 2007), in which they chose colors 6 times matching each auditorily presented CV sounds. No instruction was provided regarding the nature of the stimuli. The matched RGB values were converted into CIE xyY and Lab color coordinates for analysis. Despite the lack of participants' awareness of the consonantal nature of the auditory stimuli, CV sounds with the same glottal (e.g., /peh/, /teh/, /keh/) or the same velum (e.g., /me/, /ne/, /nge/) gestures tended to be associated with more similar colors than others indicated by closer distance on the CIE xyY color space. Furthermore, CV sounds sharing the glottal gestures synchronous with oral gestures were associated with more bluish colors whereas CV sounds sharing the velum gestures were associated with more yellowish colors than others, evidenced by a blue-yellow color axis (b*) of CIE Lab color space. These results suggest an intrinsic association between acoustic features of a subset of consonants and colors.

Acknowledgement: NRF - 2013R1A1A1010923

33.4030 Influence of visual complexity on synesthetic color choice for Japanese Kanji characters Kazuhiko Yokosawa[1](yokosawa@l.u-tokyo.ac.jp), Soichiro Takahashi[1], Michiko Asano[2]; [1]The University of Tokyo, [2]Rikkyo University

Grapheme-color synesthesia is a condition in which a visual letter or character induces a specific color sensation. Although grapheme-color association in grapheme-color synesthesia is characterized as idiosyncratic, some regularities in synesthetic sensation have also been reported. For example, Asano and Yokosawa (2012) showed that sound and meaning simultaneously affect the synesthetic color choice for Kanji script (a logographic script used in the Japanese language) in Japanese grapheme-color synesthesia. Many such regularities are related to psycholinguistic properties of graphemes, such as phonology, meaning or concepts, positions in a grapheme sequence, in addition to frequency of occurrence (e.g., Asano & Yokosawa, 2013; Simner, 2007). However, relatively little is known about the influence of more perceptual properties of graphemes on synesthetic colors, properties such as visual complexity. This study explored this issue by examining synesthetic colors for Japanese Kanji characters with both high and low visual complexity in 10 Japanese synesthetes. Results revealed that Kanji characters with high visual complexity elicited synesthetic colors that were darker (lower luminance) than those with low visual complexity. This visual complexity effect was observed even when the grapheme frequency, which is known to influence the luminance of synesthetic colors (Beeli, Esslen, & Jäncke, 2007), was controlled. Ten Japanese non-synesthetic controls were also presented with the same set of Kanji characters as the synesthetes; participants selected a color judged to "go well with the character" with each character. Results showed no effects of visual complexity. These findings suggest that not only psycholinguistic properties, but also more perceptual properties of graphemes influence grapheme-color associations of synesthetes.

33.4031 Fundamental anti-symmetries in the brain organization of conceptual knowledge representation help resolve long-standing controversies Lora Likova[1](lora@ski.org), Christopher Tyler[1], Kristyo Mineff[1], Spero Nicholas[1]; [1]Smith-Kettlewell Eye Research Institute

INTRODUCTION Conceptual knowledge allows us to comprehend the multisensory stimulation impinging on our senses. Its representation in the anterior temporal lobe is the subject of considerable debate, with the "enigmatic" temporal pole (TP) being at the center of that debate. The controversial models of the organization of knowledge representation in the TP range from a unilateral/left specialization to a fully unified bilateral TP representational system. METHODS To address these contrasting options, we developed a novel cross-modal approach in a brain imaging study of Braille Reading of descriptions of objects, faces and scenes vs Tactile Exploration of raised-line drawings of these, which were then expressed through either Braille Writing or Non-Visual Drawing guided solely by memory of the respective verbal or pictorial domain inputs. RESULTS The results revealed two functional subdivisions within TP. Remarkably, each subdivision showed previously unreported anti-symmetries such as reciprocal inter-hemispheric suppression for within-domain tasks (i.e., when both reception and expression are verbal as in Braille-Writing from reading, or pictorial, as in Drawing from haptic image-exploration). Across-domain tasks, however (such as Drawing from Braille Reading), showed symmetrical bilateral activation, implying transformation of the conceptual information from the receptive format into the format of the expressive domain (e.g., from verbal into pictorial), before the expressive performance itself. Granger causality analysis differentiated the respective source and target networks involved. CONCLUSIONS Considering the two main knowledge domains (language-mediated vs pictorial/sensory-motor), and the two main knowledge processing modes (receptive and expressive), allowed us to reveal for the first time a system of complementary symmetries, asymmetries and unexpected anti-symmetries in the TP functional organization, concerning left vs right hemisphere, activation vs suppression, cooperation vs competition. We show how, taken together these results provide a unifying explanation for the conflicting models in previous research for knowledge representation.

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33.4032 Decoding emotional valence of sounds in early visual cortex Petra Vetter[1](petra.vetter@nyu.edu), Karin Petrini[2], Lukasz Piwek[3], Fraser Smith[4], Vijay Solanki[5], Matthew Bennett[6], Frank Pollick[6], Lars Muckli[6]; [1]Dept. of Psychology & Center for Neural Science, New York University, [2]Dept. of Psychology, University of Bath, [3]Bristol Business School, University of West England, [4]Dept. of Psychology, University of East Anglia, [5]School of Critical Studies, University of Glasgow, [6]Institute of Neuroscience and Psychology, University of Glasgow

Using fMRI decoding techniques we recently demonstrated that early visual cortex contains content-specific information from sounds in the absence of visual stimulation (Vetter, Smith & Muckli, Current Biology, 2014). Here we studied whether the emotional valence of sounds can be decoded in early visual cortex during emotionally ambiguous visual stimulation. Participants viewed video clips in which two point-light walkers interacted with each other, either emotionally neutrally (having a normal conversation) or emotionally negatively (having an argument). Videos were paired with low-pass filtered soundtracks of this interaction either congruently or incongruently. Participants' task was to judge the overall emotion of the interaction. The emotionally ambiguous condition consisted of the neutral visual stimulus which could be interpreted as either a negative or neutral interaction depending on the soundtrack. The emotionally unambiguous condition consisted of the negative visual stimulus which was judged as

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negative independently of soundtrack (as confirmed behaviourally). Functional MRI data were recorded while participants viewed and judged the interaction. Activity patterns from early visual cortex (as identified with individual retinotopic mapping) were fed into a multi-variate pattern classification analysis. When the visual stimulus was neutral, and thus emotionally ambiguous, the emotional valence of sounds could be decoded significantly above chance in V1. However, when the visual stimulus was negative, and thus emotionally unambiguous, emotional valence of sounds could not be decoded in early visual cortex. Furthermore, emotional valence of the visual stimulus was decoded in both early visual and auditory cortex independent of soundtrack. The results suggest that emotional valence of sounds is contained in early visual cortex activity when visual information is emotionally ambiguous, but not when it is emotionally unambiguous. Thus, feedback from audition may help the visual system to resolve ambiguities when interpreting a visual scene, and thus may serve a function in perception.

33.4033 **Population receptive field mapping and tractography in people with absolute pitch.** Larissa McKetton[1,2](mcketton@yorku.ca), Kevin DeSimone[2,3], Keith Schneider[1,2]; [1]Department of Biology, York University, [2]Centre for Vision Research, York University, [3]Department of Psychology, York University

Introduction As the spatial resolution of functional magnetic resonance imaging (fMRI) has advanced, recent studies have been able to establish tonotopic mapping in the human auditory cortex. However, there still remains a debate of where the exact orientation of primary gradients occur in Heshl's gyrus leading to various interpretations. In our study we used fMRI to measure the population receptive fields (pRFs) in the auditory cortex to investigate underlying differences in sensory processing in absolute pitch (AP) possessors compared to age and gender matched controls. Tractography was also performed using diffusion MRI to investigate differences in connectivity in the auditory and visual structures. Methods Each participant had their cortex scanned at 1.5 ´ 1.5 ´ 2 mm3 resolution using a Siemens Trio 3T MRI scanner and 32-channel head coil. Our stimulus consisted of pure tone logarithmic chirps that enabled tonotopic and tuning width mapping of cortical regions. We analyzed the data using an adaptation of the population receptive field (pRF) technique developed by Dumoulin and Wandell (2008), used initially for retinotopic mapping of the visual cortex. Our model treated the pRF underlying each voxel's response as a one-dimensional Gaussian function of frequency providing an estimated sensitivity function for each voxel with a preferred frequency and tuning bandwidth. Diffusion tensor imaging (DTI) scans were acquired with 64 diffusion directions and tractography was performed. Results Both centre frequency and tuning width information was derived from the 1D pRF Gaussian models and plotted on the unfolded cortical surface for each hemisphere in each subject. We were able to obtain reliable tonotopic and tuning bandwidth maps as well as find differences in connectivity in humans with AP compared to controls. Conclusions Our data has helped reveal the variability and consistencies of multi-sensory processing pathways in people with AP compared to normal controls.

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33.4034 **Moving to Music: Saccadic and Motor Entrainment to a Musical Beat** Jonathan Batten[1](j.batten@bbk.ac.uk), Fred Dick[1], Tim Smith[1]; [1]Psychological Sciences, Birkbeck, University of London

It is commonplace to observe people moving their bodies to music. The bulk of research into musical entrainment utilises explicit beat matching tasks, yet there is some evidence of implicit entrainment. Changes in musical tempi influence physiological responses (heart rate and respiration), as well as the timing of motor actions, such as increased drawing speed with faster music. Eye movements have also shown to be explicitly entrained to a regular tone; fixation durations have been modulated by different musical tempi when observing scenes. However, it is currently unclear if saccadic timing can be implicitly entrained by music. This study investigated the explicit and implicit influence of musical tempo on eye movement and finger-tap timing during a sequential visual search task. Participants completed a visual search task that was either gaze or tap contingent, and either accompanied by irrelevant music, or music they were instructed to move in time with. Participants moved sequentially clockwise around 12 small black circles resembling an ellipse, identifying colour transitions (red to blue) with a single finger tap when gaze contingent, or changing the tapping hand when tap contingent. This task was accompanied either by simple music at three tempi (168, 196, 236 BPM) or silence. The tempi were informed by eye movement latencies in a silent pilot study. When explicitly tasked to move in time, both the eye movement and finger-tap latencies were significantly slower and more synchronous than when not tasked. Explicit tap responses were significantly more synchronised than eye movements, which were typically near random. The limited eye movement synchronicity suggests that individuals have limited direct control over the saccadic timer. Neither task showed any evidence of passive entrainment in the latencies or between the music and silent conditions, suggesting that motor and saccadic timing are not influenced by an irrelevant musical rhythm.

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Development: Disorders

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4035 **CRT-based Dark Adaptometry in Adults with Autism.** Rebecca Lawson[1,2](rebecca.lawson@ucl.ac.uk), Ainslie Johnstone[3], Jeremiah Kelly[4], Geraint Rees[2]; [1]Wellcome Trust Centre for Neuroimaging, University College London, UK, [2]Institute of Cognitive Neuroscience, University College London, UK, [3]Nuffield Dept. of Clinical Neuroscience, University of Oxford, UK, [4]Faculty of Life Sciences, University of Manchester, UK.

Many individuals with Autism Spectrum Conditions (ASC) experience sensory symptoms such as dislike of the dark or flashes of bright lights (Baranek et al., 1997; Kern et al., 2001; Bogdashina, 2003). We examined whether such differences in sensory experience could be caused by altered retinal function by measuring dark adaptation in a group of individuals with ASC and a group of age- and IQ-matched controls. A localised 30–98 % visual pigment bleach was performed on participants' natural pupils and then threshold sensitivity to a peripherally presented light stimulus was measured over a period of up to 30 minutes. A single exponential + linear model was fit to participants' data, producing model coefficients that capture cone and rod driven phases of visual sensitivity recovery. Modelling the data in this way produced no significant group differences for any of these measures, even when controlling for percentage photo-pigment bleach and scotopic pupil size. Exploratory analyses were carried out using the Adult Sensory Questionnaire (ASQ) scores and Autism Diagnostic Observation Schedule (ADOS) diagnoses. Model coefficients were not significant predictors of ASQ scores; however, separation of participants into groups on the basis of ADOS diagnosis revealed differences between participants with an ADOS diagnosis of Asperger's and those with a diagnosis of Autism. Further experimental testing with larger sample sizes is needed to fully understand this finding but the present results indicate that low-level adaptive processes in visual processing are largely preserved in adults with autism.

Acknowledgement: Wellcome Trust

33.4036 **Ensemble perception in autism spectrum disorder: dissociating between member identification and mean discrimination** Ruth Van der Hallen[1,2](ruth.vanderhallen@ppw.kuleuven.be), Bart Machilsen[1], Jean Steyaert[2,3], Ilse Noens[2,4,5], Johan Wagemans[1,2]; [1]Brain & Cognition, KU Leuven, Belgium, [2]Leuven Autism Research (LAuRes), KU Leuven, Belgium, [3]Child and Adolescent Psychiatry, KU Leuven, Belgium, [4]Parenting and Special Education Research Unit, KU Leuven, Belgium, [5]Psychiatric and Neurodevelopmental Genetics Unit, Massachusetts General Hospital, Boston, USA

Our visual system deals with vast amounts of information at any given moment. In order to be able to face this monumental challenge, our brains use the world's statistical regularities to process information. Local features are collapsed down and used to represent the gist, a phenomenon known as summary representation or ensemble perception. Recently, researchers studying enhanced local or reduced global visual processing in autism spectrum disorder (ASD) have started to explore ensemble perception, as it brings about a new way of tapping into these atypical processing styles. The current study is the first to investigate ensemble perception in children with ASD by (1) administering a pair of tasks pioneered by Ariely (2001), evaluating both member identification ("Was this item a member of the set?) and mean discrimination ("Was this item larger or smaller than the mean size of the set?"), and (2) manipulating the amount of external noise to allow a more detailed evaluation of task performance. Age, intellectual abilities, sensory profiles and ASD phenomenology of both the ASD group and the matched, typically developing (TD) group were taken into account (N= 46, 8-15 years). Results show that both groups were equally accurate on the member identification task, a test of "local perception", while the ASD group performed better than the TD group on the mean discrimination task, a test of "gist perception". In addition, in both tasks, performance of the TD group proved more sensitive to the degree of external noise present in the display,

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than performance of the ASD group (p < .001). Somewhat surprisingly, these results suggest that individuals with ASD are able to extract information, both at the local and global level, and information processing in ASD is more robust against external noise in the displays than in TD individuals.

33.4037 Selective impairment of perceptual closure in autism

Mohammad-Reza A. Dehaqani[1](mrabolghasemi@gmail.com), Mehdi Alizadeh Zarei[1,3], Abdol-Hossein Vahabie[1], Hossein Esteky[1,2]; [1]School of Cognitive Sciences, Institute for Research in Fundamental Sciences, Tehran, Iran (P.O. Box 19395-5746)., [2]Research Center for Brain and Cognitive Sciences, Shaheed Beheshti University of Medical Sciences, Tehran, Iran., [3]Department of Occupational Therapy, School of Rehabilitation Sciences, Iran University of Medical Sciences, Tehran, Iran

Impairment of sensory processing and integration is a hallmark of autism spectrum disorder. Basic components of fragmented image in perceptual closure need to be integrated to make a coherent visual perception. Here, we used an object naming task to test the significance of deletion of vertices vs. extended contours in naming fragmented line drawings of natural objects in typical and Autism Spectrum Disorder (ASD) children. When vertices were missing and only extended edges were visible, typical and ASD subjects performed similarly. But typical children performed significantly better than ASD children when only vertex information was visible. These results suggest that binding vertices, but not edges, to form a holistic representation of an object in children with ASD is impaired.

33.4038 Reduced Habituation to Naturalistic Stimuli in Autism

Anne Cardinaux[1](anniec@mit.edu), Hossein Nejati[1], Christy Rogers[1], Kleovoulos Tsourides[1], Tapan Gandhi[1,2], Margaret Kjelgaard[1,3], Pawan Sinha[1]; [1]Brain and Cognitive Sciences, Massachusetts Institute of Technology, Cambridge, MA, [2]Defence Institute of Physiology and Allied Sciences, New Delhi, India, [3]MGH Institute of Health Professions, Boston, MA

Background: Habituation plays a fundamental role in processing changing saliencies of environmental stimuli. Impaired habituation reduces stimulus suppression, immersing an individual in an unrelentingly salient, and potentially overwhelming, world. It would also compromise the ability to 'detach' attention from a stimulus. Impairments in habituation could account for sensory hypersensitivities as well as sustained interest in circumscribed stimuli, two prominent features of the autism (ASD) phenotype. Objectives: In prior work, we showed that habituation to low-level sensory stimuli (metronomic auditory sequences) is reduced in autistic participants compared with controls. This study investigates habituation to naturalistic audiovisual stimuli. Methods: We recorded the galvanic skin response (GSR) to repeated presentations of naturalistic video stimuli. Participants were shown 1 minute of neutral baseline stimuli, followed by five repetitions of a 30s video clip. Results: We found consistent differences in the time-course of GSR signals from ASD participants compared with age-matched neurotypical controls. For controls, GSR signals over time consistently showed a decreasing trend, indicating habituation. Conversely, for the ASD group, the GSR signals over time showed a relatively flat or increasing trend, indicating compromised habituation. Conclusions: These results may help to explain prominent features in ASD: sensory sensitivities, restricted and repetitive interests and associated behaviors such as repetitive intake of media. We argue that these findings are not due to extraneous factors such as general arousal levels, agitation, movement, or inattention, although further study is required. Future investigations will assess habituation profiles in infancy, the specificity of impaired habituation in autism compared with other conditions, and in modalities other than vision. At this stage, however, the consistency of our results across a wide range of ages and cognitive abilities points towards reduced habituation as a possible endophenotype that may yield better understanding of some key aspects of the autism phenotype.

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33.4039 How does configuration affect the allocation of visual attention in autism? A change detection study.

Jacalyn Guy[1,2](jacalyn.guy@gmail.com), Jacob Burack[3], Laurent Mottron[4], Armando Bertone[1,3,4]; [1]Perceptual Neuroscience Laboratory for Autism and Development (PNLab), [2]Integrated Program in Neuroscience, McGill University, [3]School/Applied Child Psychology, Dept of Educational and Counseling Psychology, McGill University, [4]The University of Montreal Center of Excellence for Pervasive Developmental Disorders (CETEDUM)

Individuals with Autism Spectrum Disorder (ASD) often allocate their attention to social information differently than typically developing (TD) individuals. For example, they direct their attention to the periphery, looking more at the background (i.e. the back plane) than the foreground (i.e. the front plane) of a social scene (Klin et al, 2003, Kikuchi et al, 2009). They also focus more on details rather than the context. In contrast, TD individuals devote more of their attention within a scene to the people, who are typically in the foreground. However, as TD individuals also prioritize foreground information in scenes that are void of social content, such as geometric displays, the question is whether individuals with ASD would prioritize non-social information in the foreground in a similar manner. In this study, 31 participants with ASD and 29 TD participants completed an adapted version of a change detection paradigm (Mazza et al, 2005). We measured how accurately participants could detect changes in colour between two successively presented, geometric displays. The background of the displays consisted of 20 columns comprising 10 vertically oriented rectangles (alternating between purple/green and blue/red), and the foreground consisted of 6 horizontally oriented rectangles (3 purple/green and 3 blue/red) arranged in either a circular (configural) or random (non-configural) manner. Changes occurred in either the foreground or background; the horizontal rectangles changed color in the foreground, whereas the vertical rectangles changed colour in the background. Both groups were better at detecting changes in (i) the foreground than the background and (ii) non-configural rather than configural displays. Conclusions point to a similar pattern of visual prioritization, suggesting that configuration does not differentially affect change detection in TD or ASD. Any differences in the spontaneous allocation of attention in ASD may therefore be driven more by social, rather than perceptual factors.

33.4040 Visuospatial Attention and Autism Spectrum Quotient: A Cued Line Bisection Study

Benjamin Stettler[1](bnastet@gmail.com), Lynnette Leone[1], Mark McCourt[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Introduction. Pseudoneglect (PN) refers to a tonic leftward attentional bias in neurotypical individuals, revealed by leftward misbisection of horizontal lines. PN is theorized to reflect the specialization of the right hemisphere (RH) for the deployment of spatial attention. Autism Spectrum Disorder has been variously associated with abnormal RH function such that autistic traits have been linked with increased RH lateralization (Floris et al., 2015), an unusually narrow focus of visuospatial attention (Robertson et al., 2013), delayed attentional refocusing (Ronconi et al., 2013), and reduced leftward bias in the grayscales task (English et al., 2015). We measured neurotypical performance on a cued line bisection task as a function of Autism Spectrum-Quotient (ASQ). Method. Participants (N=123, 75 female) completed the adult ASQ questionnaire (range = 2-40). PN is known to be modulated by transient visual cues delivered to the left (LC) and right (RC) line ends where left cues increase, and right cues lessen, leftward bisection error (McCourt et al., 2005). Cue duration was 60 ms and line duration was 150 ms; cue-line onset asynchrony was 120 ms. Results. There was a significant leftward bisection error in the uncued (UC) condition [$t(122) = -9.17$, $p < .001$], and a significant modulation of bisection error relative to the uncued (UC) condition by both left (LC) and right (RC) cues [LC vs. UC vs. RC: $F(1.6, 197.8) = 100.03$ (Greenhouse-Geisser correction), $p < .001$; UC vs. RC: [$t(122) = -8.14$, $p < .001$]; UC vs. LC: [$t(122) = 7.97$; $p < .001$]; LC vs. RC [$t(122) = 11.77$; $p < .001$]. However, there was no significant association between the magnitude of PN or the effect of cueing and ASQ scores. Conclusions. We find no significant differences in measures of either tonic or phasic visuospatial attention as a function of ASQ score. Power analysis revealed a 0.84 probability of finding an effect ($f2$) ≥ 0.10.

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33.4041 Motor Ability and Oculomotor Function in Children with an Autism Spectrum Disorder

Emma Sumner[1](e.sumner@gold.ac.uk), Elisabeth Hill[1]; [1]Department of Psychology. Goldsmiths, University of London

Background: Deficits in oculomotor control (i.e. suppressing reflexive saccades) have been shown to relate to language ability in Autism Spectrum Disorders. In addition to language problems, an increasing number of studies highlight motor difficulties in this population. Of note, research on supports a link between motor skill and aspects of oculomotor control, such as smooth pursuit, in children with a core motor impairment. However, very little is known about this possible relationship in ASD. The present study examined the integrity of the oculomotor system in children with and without ASD; and investigated the relationship between motor skill and oculomotor function. Methods: Twenty-two children with ASD, aged 7-10 years, were compared to 22 typically-developing children matched by age. An ASD diagnosis was confirmed with background measures, and IQ

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and general motor competency were assessed. Children completed four tasks examining oculomotor function: fixation, horizontal smooth pursuit, pro- and anti-saccades. Eye movements were recorded using the Eyelink 1000 (SR-research). Results: Children with ASD demonstrated poorer fixation stability and made more drifts away from the visual target than their peers. They were comparable to their peers on the slow speed measure of smooth pursuit, but demonstrated poorer pursuit gain in a faster task. Reflexive eye movements (pro-saccades) were similar across the two groups. However, children with ASD had more difficulty with the anti-saccade task, making many errors. Individual case analyses revealed that the children with ASD that had poorer motor skills also performed worse on the measures of fixation and smooth pursuit. Conclusions: The findings are the first demonstration of a link between motor and oculomotor difficulties in children with ASD. Further examination of oculomotor dysfunction in this population may help to identify specific neural mechanisms. Moreover, the findings highlight the need to consider co-occurring difficulties (i.e. motor skill) when interpreting eye tracking data.

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33.4042 **Autism Spectrum Disorder traits predict reduced attentional priority for faces: Fact or fiction?** Sheila Crewther[1](s.crewther@latrobe.edu.au), Andrea Wright[1], Melvyn Goodale[1,2], Robin Laycock[1]; [1]School of Psychology and Public Health, La Trobe University, [2]Brain and Mind Institute, University of Western Ontario

Individuals with Autism Spectrum Disorder (ASD) are reported to attend to social stimuli such as faces atypically, though the underlying aetiology remains undetermined. Neurophysiological factors and reduced social motivation have both been hypothesised as antecedent causal factors. The current study aimed to address this issue by comparing the speed of activation of visual attention towards faces and a non-social target category (vehicles) in low and high ASD trait groups (n=18 per group). Participants from the general population completed a self-report measure of ASD traits after which their eye movements (saccades) recorded using a high-speed eye tracker. The hypothesis that higher ASD traits would predict slower saccade onset times was supported with a strong effect size being observed for both stimulus categories. In addition there was a moderate effect for the interaction between target category and group, such that the high ASD-trait group showed a greater impairment in saccade onset for vehicle targets than faces. Our results suggest that physiological factors lead to slower activation of visual attention in individuals with higher ASD traits, regardless of stimulus category. Replication of the current study with a clinical sample and systematically varying the targets to include emotional and dynamic face stimuli is needed to assess generalisability of the findings.

33.4043 **Intact holistic processing of faces and pseudo-words in Developmental Prosopagnosia** Federica Biotti[1](Federica.biotti@city.ac.uk), Richard Cook[1]; [1]City University London

Typical observers find it harder to match sequentially presented face halves when the target regions are aligned with task irrelevant distractor halves, than when the target and distractor regions are misaligned. This "composite face effect" is thought to be a product of holistic face processing whereby information from disparate facial regions is integrated into a unified percept. Interestingly, individuals with developmental prosopagnosia (DP), a neurodevelopmental disorder associated with difficulties recognising faces, are thought to show reduced composite face interference, suggestive of aberrant holistic face processing. To determine whether reduced composite face effects previously reported in DP reflect a domain specific impairment, or a broader perceptual issue, we sought to compare composite effects seen with faces and pseudo-words, in individuals with DP and typical observers. Sixteen individuals with DP and 16 matched controls completed a simultaneous matching version of the composite paradigm. Observers were required to judge whether pairs of face or pseudo-word composites were constructed using the same upper halves. Alignment (aligned, misaligned) and composite type (faces, pseudo words) were manipulated within-subjects and interleaved within mini-blocks. In each condition, stimulus pairs were visible until participants responded. Contrary to our expectations, the two groups showed similar composite effects for both the pseudo-word and face stimuli. Observers were slower and less accurate when judging the target halves when distractors were aligned, than when misaligned. The present results indicate that individuals with DP, under some circumstances, exhibit typical behavioural markers of holistic representation. These findings challenge the popular view that the face recognition difficulties seen in DP are due to reduced feature integration. We speculate that observers with DP are able to integrate information from different facial regions, but may describe local features less efficiently.

33.4044 **Emotional influences on the identity composite effect in Autism Spectrum Disorder** Rebecca Brewer[1](r.brewer@uel.ac.uk), Katie Gray[2], Geoffrey Bird[3], Richard Cook[4]; [1]School of Psychology, University of East London, [2]School of Psychology and Clinical Language Sciences, University of Reading, [3]Department of Psychology, City University London, [4]MRC Social, Genetic and Developmental Psychiartry Department, Institute of Psychiatry, Psychology and Neuroscience, King's College London

Previous research indicates that recognising the identity of part of a face (e.g. the top half) is easier when the face is misaligned with a distractor face part (bottom half) than when the two incongruent halves are aligned, due to the two parts being 'fused', and therefore distorted, by holistic processing in the aligned condition (the 'composite face effect'). The composite face effect is widely accepted as a test of holistic processing of facial identity, but the size of this effect has varied considerably between studies. Similarly, some studies have observed atypical composite effects in those with ASD (who often exhibit identity recognition difficulties), while others have not. The composite effect has also been observed with facial emotion, however, and 'neutral' faces are often perceived to display some degree of emotion. Recent evidence suggests that the 'identity' composite effect with ostensibly neutral faces is far stronger when distractor halves are high in perceived emotion than when distractor halves are low in perceived emotion. This suggests that the composite face effect may rely on the holistic processing of facial emotion, rather than facial identity. Individual differences in emotion recognition abilities may, therefore, explain previously mixed findings concerning the composite effect in those with ASD. Previous work suggests that emotion recognition deficits in individuals with ASD are predicted by alexithymia, rather than by ASD itself. The current study investigated the impact of alexithymia and ASD on the size of the composite face effect with ostensibly neutral faces, perceived to be high and low in emotion, in 16 individuals with ASD and 16 alexithymia-matched control participants. Results indicated that the size of the composite effect for 'neutral' faces varies substantially based on emotional content and emotion recognition abilities, supporting the hypothesis that this effect relies partly upon holistic processing of emotion, not identity.

33.4045 **Children with Autism Spectrum Disorders rely on head rotation to perceive gaze direction** Diana Mihalache[1](di.mihalache@gmail.com), Michelle Salvador[2], Sophia Silver[3], Mohammad Mahoor[4], Tim Sweeny[5]; [1]University of Denver, Department of Psychology, [2]University of Denver, Department of Electrical and Computer Engineering, [3]University of Denver, Department of Psychology, [4]University of Denver, Department of Electrical and Computer Engineering, [5]University of Denver, Department of Psychology

For typical adults, gaze perception is an emergent process that relies on integrating information from both head and pupil rotations. Children with Autism Spectrum Disorders (ASD) are well known for their general deficits in global and holistic processing as well as specific impairments in perceiving eye gaze. Yet surprisingly, it is unclear how children with ASD perceive gaze when it is conveyed globally, via the combination of head and eye rotations. The current study bridges this gap. Here, children and adults viewed heads with leftward, rightward, or direct rotations in conjunction with leftward or rightward pupil rotations, and then indicated whether the face was looking leftward or rightward. We predicted that children with ASD (N=18) would rely primarily on head rotation to determine where a person is looking, whereas age-matched (M=10.14, SD=2.84) typically-developing children (TD) would integrate information from both pupil and head rotations. Indeed, children with ASD based gaze direction judgments primarily on information from head rotation, whereas surprisingly, TD children tended to utilize information from either head or pupil rotation. While both groups of children engaged a part-based analysis, favoring one feature over the other, typical adults tended to perceive gaze globally, integrating head and pupil rotations equivalently. Our findings suggest that the emergent perception of gaze direction develops gradually, even among typically developing children, and that TD children and those with ASD tend to use different facial information to determine where a person is looking. Importantly, despite general deficits in gaze perception, children with ASD are nonetheless able to rely on information from head rotation to inform judgments of gaze direction. These findings, therefore, are critical to understanding basic mechanisms of gaze perception as well as complex behaviors like joint attention and social communication among children with ASD.

33.4046 **Do children with Autism Spectrum Disorder perceive emotional faces differently?** Sandra Utz[1](sandra.utz@uni-bamberg.de), Claus Carbon[1,2]; [1]Department of General Psychology & Methodology, University of Bamberg, [2]Bamberg Graduate School of Affective and Cognitive Sciences (BaGrACS)

Regarding potential differences of people with Autism Spectrum Disorders (ASD) in processing (emotional) faces, results are ambiguous. Some studies have shown differences when faces are presented in different orientations (upright, inverted) or with different emotions, some failed to do so (e.g., Rosset et al., 2008). Quite consistently, research has revealed higher reaction times (RTs) for participants with ASD when facial emotions had to be recognized (e.g., Van Geest et al., 2002) and no difference in sensitivity to the Thatcher illusion (e.g., Rouse et al., 2004). We wanted to investigate and clarify if the combination of orientation (upright/inverted), Thatcherisation (yes/no) and emotion (neutral/happy/sad) influence the perception of faces (RTs and accuracy of oddness ratings) differently in a group of children with ASD (N = 10; Mage = 12.3 years; SDage = 3.0) and an age- and IQ-matched control group (CG; N = 17; Mage = 12.2 years; SDage = 1.0). Participants had to evaluate 192 faces according to their oddness (instead of grotesqueness because the concept of oddness was more comprehensible for 12 years old boys). Consistent with previous results, the ASD group was substantially slower compared to controls (M = 1341.2 ms; SD = 636.2 vs. M = 986.9 ms; SD = 241.8; $F(1,25)=4.94$, $p=.04$, $\eta p2$ = .17), which might indicate simpler facial processing strategies in people with ASD, e.g. by focusing on more featural aspects of faces. The ASD group reveals a considerably bigger drop in performance for inverted compared to upright faces (23% vs. 15%, $p < .001$) compared to the CG and significantly more correct responses to happy (M = 80.2%; SD = 20.2) compared to sad (M = 66.0%; SD = 23.2) or neutral faces (M = 68.5%; SD = 19.7), whereas there is no such difference in the CG. Our data display a further step towards a comprehensive understanding of ASD.

33.4047 **Association between face-specific visual abilities and social competence in autism spectrum disorders** Fakhri Shafai[1, 4](f.shafai@alumni.ubc.ca), Kimberly Armstrong[2], Grace Iarocci[3], Ipek Oruc[4]; [1]Graduate program in Neuroscience, University of British Columbia, [2]Graduate program in Clinical Psychology, Simon Fraser University, [3]Department of Psychology, Simon Fraser University, [4]Department of Ophthalmology and Visual Sciences, University of British Columbia

Autism spectrum disorders (ASD) are associated with social deficits and communication difficulties as well as stereotyped or repetitive behaviors. Neuropathology of ASD remains controversial as no isolated biomarker or dysfunction of, e.g., a single brain structure, accounts for the symptoms. Although visual symptoms are not part of the core diagnostic criteria, atypicalities in vision are prevalent in ASD. In particular, difficulties in perception and memory for facial identity, as well as expression, have been widely reported (e.g. Dawson et al. 2005, Weigelt et al. 2012). Some neuropathological models of ASD postulate a causal relationship between the social deficits and face perception problems, suggesting that an initial insult to the neural mechanisms of face processing negatively impacts the development of social skills (e.g. Schultz 2005). Such a model would require variation in face abilities among individuals with ASD to be associated with variation is social competence. Here, we examined this link for facial identity processing in a group of adults with ASD (N=31). Face memory was assessed with the Cambridge Face Memory Test (CFMT). We also measured recognition contrast thresholds for face and house stimuli in a 5AFC paradigm—face-specific perception was computed by partialing out house performance from that of face. Social competence was assessed via the Multidimensional Social Competence Scale (MSCS) (Yager & Iarocci, 2013). We also collected the following neuropsychological measures: 1) Wechsler Abbreviated Scale of Intelligence (WASI-II), 2) Autism Spectrum Quotient (AQ), 3) Autism Diagnostic Observation Schedule (ADOS). Our results showed a strong association between CFMT performance and three sub-scales of the MSCS: Social Inferencing (SI) ($p=0.027$), Social Motivation ($p=0.028$) and Nonverbal Skills ($p=0.04$). Face-specific perception was also associated with the SI sub-scale ($p=0.014$). These results are consistent with a perceptual deficit account of social impairment in ASD, at least for some aspects of social competence.

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33.4048 **Social Scene Manipulation through Gaze-Contingent Interfaces: Towards Automated Gaze Strategy Instruction for young children with ASD** Frederick Shic[1](frederick.shic@yale.edu), Quan Wang[1], Elizabeth Kim[1], Carla Wall[1], Erin Barney[1], Yeojin Ahn[1], Claire Foster[1], Marilena Mademtzi[1], Michael Perlmutter[1], Suzanne Macari[1], Katarzyna Chawarska[1]; [1]Yale Child Study Center, School of Medicine, Yale University

Most eye tracking studies only recorded participants' eye movement during passive viewing, used static images, and manually defined boundaries of areas of interest (AOIs). In the present study, we investigate how typically developing (TD) toddlers and toddlers with ASD attend to dynamic social scenes in an interactive gaze paradigm. Each toddler viewed four categories of dynamic video stimuli: Motherese, Body Movements, Activity with Objects, and Singing Songs. Participants included 31 TD toddlers and 9 toddlers with ASD. All TDs were assigned to the regular, non-Gaze Contingent (non-GC) viewing condition, and their data was used for normative gaze pattern. Among ASD toddlers, five were assigned to the Gaze Contingent (GC) condition. Subsequently dynamic heatmaps of the normative gaze pattern were applied to construct a corresponding set of attention-redirecting videos which darkened and blurred areas where the TD toddlers were not looking. If the participants in the GC condition looked away from normative attention areas, the next video frame switched to the attention-redirecting video with bright and sharp regions corresponding to TD's heatmap distribution. In all four categories of videos toddlers with ASD had significantly shorter looking times compared with TD toddlers ($p < 0.001$). Furthermore, a linear mixed model analysis showed that toddlers with ASD, but not TD toddler, looked significantly less at Motherese dyadic speech videos compared to the other three categories ($p < 0.001$). With GC adaptive training, toddlers with ASD maintained their attention better than in the non-GC condition ($p < .05$). The preliminary data provide support for the application of GC training as a viable option for attaching visual attention and modifying gaze behaviors in toddlers with ASD. By improving looking strategies of toddlers with ASD, we hope to broaden their future access to social learning opportunities during this period of great neuroplasticity.

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33.4049 **Visual Backward masking: a comparison between schizophrenia, depressive, schizoaffective, and bipolar patients** Maya Roinishvili[1,2](m.roinishvili@agruni.edu.ge), Eka Chkonia[1,3], Liza Reichard[4], Wenke Wurch[4], Hendrik Puhlmann[4], Cathleen Grimsen[4], Michael Herzog[5], Andreas Brand[6]; [1]Institute of Cognitive Neurosciences, Agricultural University of Georgia, Tbilisi, Georgia, [2]Vision Research Laboratory, I. Beritashvili Center of Experimental Biomedicine, Tbilisi, Georgia, [3]Department of Psychiatry, Tbilisi State Medical University, Tbilisi, Georgia, [4]Institute of Human Neurobiology, University of Bremen, Bremen, Germany, [5]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, [6]Institute for Psychology and Cognition Research, University of Bremen, Bremen, Germany

In visual backward masking, a target is followed by a blank screen (ISI - Inter-stimulus-interval) and, then, a mask which deteriorates target processing. Schizophrenic patients show strong but complex processing deficits in visual masking compared to healthy controls. Recent genetic, behavioral, and clinical studies suggest that functional psychoses (schizophrenia, bipolar disorder, schizoaffective disorder), previously thought to be distinct from each other, belong to one continuum. The shine-through masking paradigm has been proven to be a reliable endophenotype of schizophrenia with a high sensitivity and specificity discriminating between patients, their clinically unaffected relatives, and healthy controls. Here, we examined whether the complex masking effects, we found in schizophrenia patients previously, are also found in other psychotic and non-psychotic patients, namely, depressive patients and abstinent alcoholics. We tested 28 schizophrenic, 22 schizoaffective, 20 bipolar patients, 26 major depressive patients, 23 abstinent alcoholics, and 24 healthy control subjects with various variants of the shine-through masking paradigm. All 3 groups

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of psychotic patients showed a very similar pattern of masking deficits. Masking was strongly prolonged compared to controls: Schizophrenia patients needed ISIs of 110 ms, bipolar patients of 125ms, schizoaffective patients of 130 ms and controls of only 30ms. These prolonged ISIs were not caused by deteriorated spatial or temporal resolution as two additional experiments show. Interestingly, patients with unipolar major depression and abstinent alcoholics performed like healthy controls. We suggest that patients with functional psychoses suffer from similar visual dysfunctions whereas visual processing of depressive patients is different. Key words: visual backward masking, visual processing, functional psychoses

33.4050 **Using a three-dimensional multiple object tracking paradigm to train attention in students with a learning disability**

Domenico Tullo[1,2](domenico.tullo@mail.mcgill.ca), Jacalyn Guy[1,2], Jocelyn Faubert[3,4], Armando Bertone[1,2]; [1]Perceptual Neuroscience Laboratory for Autism and Development, [2]McGill University, [3]Laboratoire de psychophysique et de perception visuelle, [4]Université de Montréal

Decreased selective and sustained attention abilities are often characteristic of atypically developing populations (Koldewyn, et al., 2013). Consequently, several cognitive-based training approaches have been developed to remediate such difficulties by targeting these particular subcomponents of attention (Sonuga-Barke et al., 2014). Multiple object tracking (MOT) paradigms are (i) a measure of sustained, selective, dynamic and distributed attention, (ii) non-verbal in nature and (iii) accessible to students with different levels of cognitive and language functioning. We examined the efficacy of a novel, 3D-MOT attention training program (NeuroTracker) to assess whether increased 3D-MOT performance transferred to another test of attention (i.e., near-transfer; Redick et al., 2014). In our pilot study, a group of adolescents (n = 30; 12 - 17 years old) with a developmental and/or learning disorder underwent a pre-training assessment of IQ (Wechsler Abbreviated Scale of Intelligence - II [WASI-II]) and attention (Continuous Performance Test - 3 [CPT-3]). Pre-training analyses revealed an association between 3D-MOT performance with both, perceptual (non-verbal) reasoning intelligence measure (r2 = .55) on the WASI-II, and overall CPT-3 performance (r2 = .20). Participants were then randomly assigned to (i) experimental (n= 10), (ii) control (n = 10), or (iii) treatment as usual (TAU) groups (n = 10). The experimental group received 3D-MOT training three times a week, over a period of five weeks (15 sessions), while the control group played a puzzle-like math game. Results revealed an improvement in CPT-3 scores in the experimental group following the training period, with performance improving an average of 10%; no significant changes were found for either control or TAU groups. These results suggest that 3D-MOT can explain a large portion of the variance in intelligence and cognitive functioning specific to a specialized population. Moreover, the near-transfer effects found here provide the basis for examining the far-transfer of 3D-MOT-related improvements in attention to academic success (i.e., mathematics).

33.4051 **Dyslexia prevention by action video game training: behavioural and neurophysiological evidence**

Simone Gori[1,2](simone.gori@unibg.it), Sara Bertoni[3], Maria Sali[2], Milena Ruffino[2], Sandro Franceschini[2,3], Luca Ronconi[2,3], Massimo Molteni[2], Andrea Facoetti[2,3]; [1]Department of Human and Social Sciences, University of Bergamo, Bergamo - Italy, [2]Developmental Neuropsychology Unit, Scientific Institute E.Medea, Bosisio Parini, Lecco - Italy, [3]Developmental and Cognitive Neuroscience Lab, Department of General Psychology, University of Padua, Padua - Italy

For children affected by developmental dyslexia learning to read is extremely difficult. Pre-reading visual attention predicts future reading acquisition skills. Action video game (AVG) training increases attentional functioning and induces learning that transfers well beyond the task domain, such as reading. We investigated the effects of AVG training on predictors of future reading acquisition (i.e., visuo-spatial attention, auditory-phonological processing and rapid naming skills) and on the dense-array EEG resting-state in pre-reading children at risk for dyslexia. Three matched groups of pre-readers at risk for dyslexia were tested before and after they played with AVG, non-AVG (for 20 hrs) or no-treatment (Exp. 1). We found that only playing AVG improved children's visuo-spatial attention processing. Phonemes discrimination was also increased only after AVG training. We confirmed this effect of AVG training on phonological processing in a replication study with another independent sample (Exp. 2). Two new samples of pre-schoolers at risk for dyslexia were selected (Exp. 3): half of them were trained with AVG while the other half had no training. We measured visuo-spatial attention and auditory-phonological skills. Eyes-closed resting-state EEG was also recorded in both groups. Results showed that only the AVG training improved visuo-spatial attention as well as auditory-phonological skills. A reduction of the upper alpha band (10-14 Hz) oscillatory activity in posterior areas was found only after the AVG training, showing a possible neural basis of the effect of attentional improvement on auditory-phonological processing. Our results showed, for the first time, that attention improvements can directly translate into better language abilities, providing a new, fast and fun prevention training for dyslexia.

Face Perception: Social cognition 1

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4052 **The Role of the Eyes and Makeup in Attractiveness**

Jessie Peissig[1](jpeissig@fullerton.edu), Amanda Killian[1], Maedeh Mousavi[1]; [1]California State University Fullerton

The makeup industry in the United States earns billions each year, suggesting makeup plays an important role in attractiveness. Russell (2009) showed that increased luminance contrast in the eye and mouth regions of the female face lead to increased attractiveness, suggesting that makeup increases attractiveness due its ability to increase the contrast differences between those regions and the rest of the face. In this study 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. We used images of thirty individuals, shown in grayscale both with and without makeup. Thirty-two participants judged the attractiveness of this set of faces in which makeup was added to the upper eye region, directly under the eyes, or the lips. In the first experiment the original faces and the faces with makeup were shown in separate blocks to eliminate any effects of seeing the same faces with and without makeup within the same block. In a second experiment, 34 participants judged a set of faces that was chosen so that the attractiveness across conditions was equal and within a narrow range, to control for the effects of extremely attractive and unattractive faces. Both experiments showed that makeup application does affect female attractiveness ratings perceived by others. The placement of the increased contrast using makeup was critical. If makeup was applied under the eyes, attractiveness ratings were significantly lower when compared to faces with no makeup. Makeup applied to just the lips had a minimal effect on attractiveness ratings. In contrast, if makeup was applied to the upper eye region attractiveness ratings were significantly higher. These results suggest that the contrast effect on attractiveness is driven primarily by increases in contrast in the upper eye region.

33.4053 **A group's facial attractiveness is the average attractiveness of its members**

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How do people judge groups in terms of attractiveness? We investigated whether people compute and utilize the average attractiveness of group members. In Experiment 1, two groups of participants rated the attractiveness of 240 face images. One group rated one by one and the other group rated set by set (consists of 4 faces). We found that the attractiveness rating for a set of four faces was equivalent to the arithmetic mean of ratings for each face in a set. In Experiment 2, we modulated the attractiveness variance within a set and asked participants to rate the attractiveness of a set as a whole. The attractiveness rating of a set was equivalent to the arithmetic mean of ratings of its members, only when the attractiveness variance was low. These patterns were maintained whether a set of faces was presented for either 500ms or 2000ms. These results suggest that the visual system efficiently computes the average attractiveness of group members, when the faces are similarly attractive. Finally, Experiment 3 investigated whether participants' judgments on the average attractiveness of faces in a group were biased towards the most attractive face in the group. Here, participants were asked to detect a probe presented after each group of faces. Reaction time (RT) to the probe replacing the location of the most attractive face did not significantly differ from the RT to the probe replacing the locations of the other faces, suggesting that the visual system averages all faces in a group with equal weights.

33.4054 **The effect of variance in group members' attractiveness on the perceived facial attractiveness of small groups**

Jun Kawahara[1](jkawa@let.hokudai.ac.jp), Yuka Kobayashi[2], Michiteru Kitazaki[3]; [1]Department of Psychology, Hokkaido University, [2]Department of Psychology, Chukyo University, [3]Toyohashi University of Technology

Representing multiple objects as an ensemble allows for simultaneous visual processing of the objects. The present study examined the effect of varying the attractiveness of individual group members on the attractiveness ratings of the group as a whole. Given that average faces are perceived as beautiful, large variations the attractiveness of individual group members should reduce the attractiveness of the whole group more so than small variations, even when the groups are matched for average attractiveness. Participants viewed a pair of different faces and rated the subjective physical attractiveness of the pair as a whole using a visual analog scale. High- and low-attractiveness pairs were created such that the average baseline attractiveness rating (pre-rated by other raters) of each high- and low-attractiveness pair was comparable. The perceived attractiveness of the low-attractiveness pairs was negatively correlated with the variation in baseline attractiveness; this indicates that the perceived attractiveness of low-attractiveness pairs is lower when differences between the members are larger. This trend was not observed in the high-attractiveness pairs. Similar patterns of results were observed in two follow-up studies, in which three faces were presented for 3s or 1s. Multiple regression analyses, which included average group attractiveness and variance in attractiveness as explanatory variables, and perceived attractiveness as the response variable, revealed that variance in the low- and middle-attractiveness groups was negatively correlated with perceived attractiveness; no such trend was observed in the high-attractiveness group. These results indicated that a large variation in members' attractiveness decreased the perceived attractiveness of the lower-attractiveness groups when the groups comprised two or three images. Simultaneous extractions of attractiveness from at least three facial images may not require attentional resources.

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33.4055 Understanding the social dimensions of facial attractivenss

Amanda Song[1](feijuejuanling@gmail.com), Linjie Li[2], Vicente Malave[1], Angela Yu[1], Garrison Cottrell[3]; [1]Cognitive Science Department, University of California, San Diego, [2]Electrical and Computer Science Department, University of California, San Diego, [3]Computer Science and Engineering Department, University of California, San Diego

What makes a face attractive has long been an interesting topic in face perception research. Previous studies have shown that an attractive face is conferred with other positive social attributes, such as trustworthiness, and industriousness; conversely, attractiveness appears to be at least partially predictable from other perceived attributes, such as averageness and familiarity. To better understand facial attractiveness in the context of social attributes of faces, we investigate the relationship between facial attractiveness and multiple social attributes of faces based on a large face dataset with social feature ratings and attractiveness ratings (Wilma, Isola, & Oliva, 2013). It provides attractiveness ratings and social feature ratings of over 2000 faces. Correlations between every social feature and attractiveness show that 37 of them are significantly correlated with attractiveness ($p< 0.001$). We calculate how much variance each individual social feature explains in attractiveness ratings. The top 5 positively correlated social feature predictors are: interesting (correlation coefficient: 0.66, explained variance: 43%), sociable (0.60, 39%), memorable (0.54, 29%), confident (0.53, 28%), normal (0.53, 28%), whereas the top 5 negatively correlated social feature predictors are: boring (-0.59, 35%), weird (-0.56, 31%), forgettable (-0.51, 26%), introverted (-0.49, 24%), and unhappy (-0.47, 22%). Since social attributes are highly correlated, we use principal component analysis to get an orthogonal feature matrix, then re-calculate how many principal components are correlated with attractiveness. This time, we find that only 11 principal components significantly correlated ($p< 0.001$) with attractiveness. We computed the prediction error (MSE±SD) as a function of the number of reduced dimensions and find that the average prediction performance in the test set indeed reaches a plateau after 11 dimensions (MSE±SD ≈ 0.7 ± 0.05). This suggests that social attributes can serve as good predictors of attractiveness and the intrinsic dimension relevant to it is 11.

33.4056 Are we looking for love in all the wrong faces?

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Millions of people use online dating sites each day, scanning through streams of unfamiliar faces in search of an attractive mate. Face images, like most visual stimuli, are subject to processing whereby the current percept is altered by exposure to previous visual input. Recent studies using rapid sequences of faces have found that perception of face identity is biased towards recently seen faces, promoting identity-invariance over time. Here we examine whether the attractiveness of a face is contingent upon the attractiveness of a recently seen face. We designed a binary task mimicking the selection interface popular in online dating websites in which observers typically make binary decisions (attractive or unattractive) about each face in a sequence of unfamiliar faces. Interestingly, even though we used images from an online dating site, the attractiveness of a face depended on the attractiveness of the face on the preceding trial. That is, a face was rated as more attractive when the face on the preceding trial was more attractive compared to average, and less attractive if the preceding face was less attractive. In a second experiment we examined whether the inter-trial attractiveness effect is due to a perceptual phenomenon or a response bias by manipulating face orientation (inverted or upright). Interestingly, we replicated the inter-trial effect, but only when the preceding trial's face had the same orientation as the current trial's face (both inverted, or both upright), suggesting that the effect is due to a perceptual phenomenon. Our results demonstrate that judgments of face attractiveness are influenced by information from our evaluative and perceptual history and that these influences impact our behaviour in the context of binary classifications commonly used in online dating.

33.4057 Facial contrast affects the perception of skin homogeneity and wrinkles

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Introduction Several age-related facial features are contrast-related. Among these are skin homogeneity (the evenness of the reflectance properties of the skin surface), wrinkles, and facial contrast (the color and luminance differences between facial features and surrounding skin). With age, wrinkles increase, skin becomes less homogeneous, and facial contrast decreases. Both skin homogeneity and facial contrast are increased by makeup. We observed anecdotally that faces with increased facial contrast (both in images and in live faces with cosmetics applied to the facial features) appeared to have more even skin tone and/or smaller wrinkles. Following these observations, we experimentally tested the hypothesis that facial contrast affects the perception of skin homogeneity and wrinkles. Methods We artificially increased or decreased facial contrast using Photoshop in full-face images of 30 women aged 21 – 59. Critically, the manipulations of facial contrast changed the color of the facial features but not the skin, which was identical in the two conditions. Sixty-six observers gave ratings on 1-7 Likert scales of skin evenness and wrinkling. Results There were clear effects of facial contrast. Faces with increased facial contrast were rated as having skin that was significantly more even and less wrinkled. Unsurprisingly, there were also clear effects of face age, with older faces being rated as having skin that was significantly less even and more wrinkled. There was no interaction between facial contrast and face age. Conclusions These findings support the hypothesis that facial contrast affects the appearance of skin homogeneity and wrinkles. This may shed new light on the visual effects of makeup. By increasing facial contrast, makeup may reduce the appearance of spots and wrinkles. Spots, blemishes, and wrinkles all increase the visual contrast of skin texture. We speculate that the phenomenon observed here is related to contrast gain control or contrast adaptation.

33.4058 An other-age effect in facial trustworthiness perception

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Participants make multiple social judgments reliably and accurately from briefly-presented face images. In particular, trustworthiness appears as a core dimension in social "face space" and may be an important personality trait that observers estimate from faces. Like other aspects of face perception, perceived trustworthiness is subject to out-group effects for categories like race, but it's unknown whether trustworthiness is impacted by other face categories. We examined whether observers exhibited an other-age bias for facial trustworthiness estimates. Our participants viewed briefly-presented (200ms) young (18-29yrs), middle-aged (30-49yrs), and older adult (50-69yrs) faces and rated trustworthiness on a 6-point Likert scale. We asked two questions about these ratings as a function of age group: (1) Do trustworthiness ratings differ across age groups? (2) Does inter-rater agreement differ across age groups? To address this latter question, we measured within-participant reliability and inter-subject reliability using intra-class coefficients (ICCs) to compare group agreement to individual reliability in all age groups. We recruited 47 participants (24 male) from NDSU's undergraduate study pool. Mean trustworthiness ratings across groups reflected a significant effect of age group (,$F(2,45)=15.4$, $p< 0.001$), such that trustworthiness ratings for younger faces ($M=4.38$) were signifi-

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cantly higher than ratings for older faces (M=3.99) and middle-aged faces (M=4.05). We also found that the relationship between group reliability and internal reliability differed across age groups. ICCs for group reliability were significantly lower than those for internal reliability in younger and middle aged-faces, but this was not true for older faces. That is, young observers rating older faces disagreed with each other less than they agreed with themselves, suggesting differing levels of group consensus as a function of face age. We conclude that face age impacts trustworthiness estimates and discuss this result in the context of other out-group face recognition effects.

33.4059 **Dominance Elicits the Own-Gender Bias in Males** Natalie Motta-Mena[1](nvg109@psu.edu), Giorgia Picci[1], K. Suzanne Scherf[1]; [1]Psychology, The Pennsylvania State University

People use the structure of the human face to form social impressions. These social dimensions of face processing have direct relevance for motivating social behavior, like selecting and competing for potential mates. Therefore, men and women may be differentially sensitive to the visual information relevant to these dimensions. For example, structural characteristics of faces that convey dominance (e.g., signals of physical strength) may be especially relevant for males when considering behavior related to male-male mate competition. Here, we evaluated the hypothesis that priming males to attend to dominance cues (but not likability cues) in other male faces would instigate heightened sensitivity to male faces in subsequent tasks of face processing. Adult male and female participants were tested in a series of face processing tasks that included measuring the perceptual sensitivity to dominance, likability, and facial expressions, as well as face recognition for both male and female faces. Half the participants began the testing with the dominance task and the other half with the likability task. We predicted that males, but not females, who executed the dominance but not the likability, task first would subsequently exhibit an own-gender bias in the face recognition and expression detection tasks; that is, superior recognition and sensitivity for detecting expressions in male compared to female faces. Indeed, compared to males who received the likability task first, males who processed dominance in faces prior to the other tasks consequently exhibited the own-gender bias in the subsequent face processing tasks. Females did not show any such biases as a function of which face attribute task they performed first. These findings suggest that, contrary to the existing literature, there are conditions under which males do exhibit an own-gender bias in multiple aspects of face processing and that females do not always show superior face processing abilities.

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33.4060 **The Longer I See You, the Angrier You Look: The Time Course of Other-Race Effects in Expression Recognition** Cindy Bukach[1](cbukach@richmond.edu), Lauren Nagasugi[1], Melanie Cooke[1], Jessie Peissig[2]; [1]Dept of Psychology, University of Richmond, [2]Dept of Psychology, California State University Fullerton

Caucasians are biased to perceive angry expressions in Black faces, resulting both in greater accuracy for recognition of angry Black faces (Albright et al., 2006) and a tendency to misinterpret Black neutral expressions as angry (Maner et al., 2005). Here, we investigated how rapidly other-race effects for emotional expression emerge by manipulating exposure duration of emotional Black and Caucasian faces masked by happy faces before and after target presentation. Target emotions were neutral, angry, disgust, fear and sad. Target exposure durations were 50, 100, 150, 200 ms. 17 Black and 28 Caucasian participants were tested. Chi Square analysis revealed that in general, Caucasians were more likely to respond "angry" to Black than Caucasian faces ($p = .014$), whereas Caucasians were more likely to respond "fearful" to Caucasian than Black faces ($p < .001$). Black participants were more likely to respond "sad" to Caucasian than Black faces ($p = .05$). Analysis of the angry expression condition revealed greater accuracy for Black than Caucasian faces only for Caucasian participants. This effect emerged in the 100 ms exposure duration, and increased linearly as exposure duration increased, $F(1, 27) = 7.329$, $\eta 2 = .213$, $p = .012$. Interestingly, both Black and Caucasian participants were equally more likely to respond "angry" to Black neutral faces than Caucasian neutral faces, and this bias also emerged at 100 ms and increased linearly with exposure duration. However, by 200 ms, the bias disappeared for Black participants (bias = 0) whereas it continued to increase for Caucasian participants (36% more likely to respond Angry to Black neutral faces than Caucasian neutral faces). These results suggest that both Black and Caucasian participants have an angry-Black face bias, but that the processes underlying the biases in the two groups diverge at around 200 ms of exposure duration.

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33.4061 **Summary Statistics for Gaze and Head Direction over Time** Joseph Florey[1](j.a.florey@qmul.ac.uk), Steven Dakin[2], Colin Clifford[3], Isabelle Mareschal[1]; [1]Experimental Psychology, Queen Mary University of London, [2]Optometry & Vision Science, University of Auckland, [3]Psychology, University of New South Wales

INTRODUCTION: Average properties of facial identity or emotion can be extracted over both space and time (e.g. Haberman & Whitney, 2009). We have previously shown that average head rotation is more efficiently encoded than gaze deviation over space (Florey et al VSS 2015). Here, using a temporal averaging paradigm to approximate natural viewing behaviour, we examine whether this superiority for head averaging persists and whether judgments of gaze and head direction are prone to recency effects. METHODS: Each trial consisted of a sequence of 8 faces, whose head rotation or gaze deviation were drawn from a normal distribution (sd =16°) with a mean that varied from trial to trial. At the end of each trial (240 per condition), participants (n=19) indicated their perceived mean gaze deviation (head rotation) of the set using an on screen pointer. RESULTS: The standard deviation of participants' responses from the true mean was used as a measure of accuracy. Regression coefficients for each face in the sequence were calculated using a linear regression model. No significant difference was found in participants' accuracy between judging average gaze (mean = 15.8°) or head directions (mean = 14.1°). The regression coefficients indicated all items were being used in participants' estimated average and showed a significant recency ($p < .01$) effect for the gaze deviation task across all participants but surprisingly not for head rotation. CONCLUSIONS: Observers can average both head rotation and gaze deviation over time, with only gaze deviation judgements showing recency effects. Surprisingly, accuracy of response does not depend on the strategy used (e.g. recency) to perform the task suggesting that other factors such as working memory and internal noise may play a greater role in temporal averaging.

33.4062 **You not me: others' emotional facial expressions capture attention automatically – but only for empathic people.** Christian Wallraven[1](christian.wallraven@gmail.com), June Kang[2,3]; [1]Brain and Cognitive Engineering, Korea University, [2]Department of Biomedical Science, Korea University, [3]Empathy Research Institute, Seoul, Republic of Korea

Facial expressions are processed effortlessly and quickly, allowing us to assess a person's mood and emotion. In addition, emotional facial expressions are known to preferentially attract attention for visual processing. This preferential attention, however, may be mitigated by individual differences in traits – in particular, we speculated that highly empathic people may process emotional expressions more efficiently than non-empathic people. To study preferential attention in facial expression processing, we used the attentional blink paradigm in which identification of a first target (T1) transiently impairs the detection of a second target (T2) during rapid serial visual presentation of a stimulus stream. If emotional expressions are processed preferentially by empathic people, then the impairment for T2-stimuli should be less compared to non-empathic people. Crucially, however, this effect should only occur for faces of others but not for one's own face. To test this, we recruited 100 participants and split them into low- (N=34), medium- (N=47), and high-empathy (N=19) groups based on self-reported levels of emotional empathy. Stimuli consisted of happy, sad, and neutral expressions from the Korean Facial Expressions of Emotion resource for other-face stimuli. In addition, we recorded and validated these three expressions for all participants for use as own-face stimuli. A standard attentional-blink paradigm was implemented with neutral faces as T1-stimuli and emotional faces as T2-stimuli in Psychtoolbox-3. In accordance with our hypothesis, the amount of impairment correlated significantly with the self-reported empathy score only for the other-face condition, but not for the own-face condition. Overall, the high-empathy group showed significantly less impairment for other-face emotional faces compared to the two other groups. These results clearly show that emotional expressions preferentially capture the attention of empathic people. Our findings also provide support for a previously untested component of the Perception-Action-Model of empathy that posits automatic, preferential processing for emotionally-charged stimuli.

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Object Recognition: Mechanisms and models 2

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4063 Overlap in performance of CNN's, human behavior and EEG classification

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Convolutional neural networks (CNNs) have begun to rival human performance in terms of identifying classes of images from specific datasets. The CNN architecture roughly mimics the hierarchical visual processing of the ventral stream and these CNNs have been used successfully to explain a significant portion of neural responses in the human ventral cortex. We compared performance on an animal/non-animal categorization task based on 1) human behavior, 2) CNN scores, and 3) classification using EEG measurements. Images differed in their complexity, as indexed by their Spatial Coherence (SC) and Contrast Energy (CE) and were unknown to both the network and the human observers. Our results show a remarkable overlap in the behavior of the CNN, EEG classification and human behavior. All three perform best for images with a medium complexity and worst for images with a high complexity. Importantly, inspecting the type of errors, we observe that for images with a low and medium complexity by far most mistakes are made on trials in which an animal is present and the CNN, humans and EEG classifier fail to pick this up. For complex images the proportion of false alarms and misses are much more comparable. Looking at the results from the EEG classifier, we further observe that the classification reliability of animal vs. non-animal peaks between 300 and 400 ms. These results indicate that the object recognition process of both human (behavior and EEG) and CNN is influenced by the complexity of an image. This overlap strengthens the idea that CNNs are accurate models for human visual perception.

33.4064 Probing human intracranial visual responses with commercial movies

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The visual system can effortlessly parse a range of visual information from rich, dynamic input. Most visual neuroscience studies, however, have focused on responses to static images devoid of temporal context. Here we use intracranial electrocorticography (ECoG) recordings from patients watching commercial movies to interrogate the brain's response to more naturalistic visual stimuli. Using commercial movies as stimuli presents many advantages. First, they contain visual information that more closely mimics humans' day-to-day visual experience. Second, and perhaps most importantly, movies contain rich social narratives that provide information at many different levels, from low level visual (e.g. large changes in contrast and illumination when the camera cuts between views) to higher-level social dimensions (e.g. faces, emotions, and social interactions). Although these movies are shown only once to each subject, we can leverage the fact that each movie contains multiple scenes in which similar visual input (e.g. same faces, scenes, etc.) occurs, and use these for repeated measures. Through this analysis we find that the physiological responses at many electrodes, particularly in occipital and temporal regions, are strongly modulated by camera cuts. Despite the dynamic and heterogeneous nature of the stimuli in every cut, several electrodes show a vigorous and reliable response in the majority of cuts. Further, our initial results suggest that these responses are modulated by the content of each sequence of frames, as evidenced by our ability to decode the presence or absence of faces in single cuts. This work shows that these movies, despite inhomogeneity between cuts and lack of repetitions, provide a rich stimulus set for examining visual phenomena. These results provide data and a framework for investigating the neural basis of higher-level visual processing.

33.4065 Visual and Semantic Neural Representations For Animate and Inanimate Object

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When we view a picture or read a word, we evoke its meaning (semantics) based on prior knowledge of the concept. We previously showed that pictures and words describing scene categories evoke similar representations in the inferior frontal gyrus, precuneus, angular gyrus and ventral visual cortex. Although we know the neural representations of pictures of tools and animals differ, are there similar differences when these concepts are evoked through words? To examine the nature of differences and similarities between these concepts, we examine the neural activity for pictures and words using a classifier to decode the BOLD signal within modalities and across modalities via multivariate pattern analysis (MVPA). We used picture stimuli of animate and inanimate exemplars from twenty-four categories derived from six superordinate classes (big cats, insects, birds, vehicles, tools and fruits). Word stimuli were approximate "captions" of the types of pictures used for the same category (e.g. 'a panther hunting at night'). In the fMRI experiment, subjects passively viewed first all the word stimuli for all twenty-four categories and then the picture stimuli for the same categories. A whole brain MVPA searchlight with six-way classification and a fine-grained four-way sub-class classification was performed. The six-way results from decoding using only the word stimuli revealed a distributed set of brain regions in the left hemisphere, including, the angular gyrus, precuneus, inferior frontal gyrus and putative visual areas in the lateral and ventral occipito-temporal cortex. Picture decoding was more extensive but revealed these same regions. Like natural scenes, we found that we could cross-decode between words and pictures of objects in inferior frontal gyrus, precuneus, angular gyrus, consistent with these regions being category general semantic hubs whereas the ventral visual regions show a differential specificity between the concepts for animals, tools and natural scenes.

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33.4066 Semantic object grouping in the visual cortex seen through MVPA

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Visual object perception recruits a network of cortical regions to extract diverse semantic properties from layers of visual information. Regions selective for a few selected object classes, such as faces, places, and hand-writing, have become well-established. However, the cortical encoding of broader semantic properties is subject to ongoing study. Here we use an fMRI voxel searchlight method to compare local cortical responses to 60 visual objects with 218 semantic groupings of the same 60 objects. The semantic groupings are drawn from Palatucci et al. (2009) to capture information about object action, identity, typical-location, tactile-feel, etc. Cortical data are drawn from an earlier study by Leeds et al. (2013). Using representational similarity analysis, we identify a division of labor in semantic representation among mid-level stages of the ventral object perception pathway, particularly involving lateral occipital, fusiform, and inferiortemporal cortex. We find each region is associated with a subset of multiple semantic properties. Identity properties such as "is it a mammal?" or "is it a vehicle?" show particularly strong cortical matches above other properties such as emotion ("is it friendly?"). Our observed semantic-neural matches partially overlap with those reported earlier by Sudre (2012) in MEG, who explored the same set of semantic properties. Differences between our findings may stem from alternate neural coding strategies at different spatial scales, providing complementary perspectives on semantic object groupings in mid-level visual regions in the cortex.

33.4067 Visual object responses of the ventral stream reflect both size and motor-relevance

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Visual non-animate object representations in the occipito-temporal region can be distinguished by their real-world size, with stronger responses to smaller objects in lateral areas, and stronger responses to larger objects in medial areas. However, small objects tend to be manipulated more while larger objects tend to stand as support for other objects. Thus, the observed separation of these neural responses may reflect information about the motor-relevance of these objects, rather than their size. To examine this hypothesis, we directly compared the dimensions of real-world size and motor-relevance. A stimulus set was created with small motor-relevant, small non-motor-relevant, large motor-relevant and large non-motor-relevant objects, with 18 different objects per condition. We collected fMRI data from 21 subjects who observed these objects. First we explored targeted scene- and object-regions to observe whether they show a modulation by motor-relevance instead of, or in addition to, size. Activity in these regions was indeed modulated by the motor-rele-

vance of the objects, and also independently by real-world size. Next, we examined responses across the whole brain. The big/small regions identified in previous studies were replicated, but these same regions were also independently sensitive to motor-relevance. Interestingly, we found that regions with a big-size preference have a non-motor-relevance preference, and regions with a small-size preference have a motor-relevance preference. Thus, while size and motor-relevance dimensions were pitted against each other in this experiment, the neural responses to the two dimensions were aligned, suggesting an "ecological organization." In the world, small-sized objects tend to be higher in motor-relevance, while large objects are usually lower in motor-relevance, and the large-scale neural responses of occipito-temporal cortex reflect this ecological covariation.

33.4068 Investigating functional organization with Grouping by Response Similarity

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Cortical parcellation has been conducted using gene expression, cytoarchitectonics, receptor architecture, connectivity, and intrinsic activity; however, stimulus-driven functional parcellation has remained elusive, particularly for the ventral temporal cortex (VTC). While several category-selective regions (e.g. face and scene areas) have been identified, these occupy less than half of non-retinotopic visual cortex. Whether the remaining cortex contains distinct functional regions remains unknown. Representational Similarity Analysis (RSA) is a powerful tool for studying these regions, however, the logic of RSA requires a region of interest (ROI) containing a unitary, complete representation. Here, we show that Grouping by Response Similarity (GRS), a data-driven method for identifying regions containing functionally coherent responses, can identify regions containing distinct representations as demonstrated using RSA. During two fMRI sessions, subjects viewed separate sets of video clips of naturalistic stimuli while performing a one-back task. For each dataset, a vector of responses to each stimulus was calculated for each VTC vertex. In order to group functionally similar vertices, response vectors were correlated and the correlation matrix was then permuted to maximize the summed values along the subdiagonal. An automated segmentation method identified functional clusters in the matrix, which were projected onto the cortical surface. Importantly, the algorithm finds regions with coherent responses without assumptions regarding the relationships between stimuli or spatial locations. Functional clusters in the GRS matrix produced discrete ROIs on the cortical surface, resulting in parcellation of the VTC. ROI stimulus preferences were replicable across split halves of the data through much of VTC and ROI boundaries were replicable across the two naturalistic stimulus sets. RSA within these ROIs demonstrated that the ROIs encode distinct representations of the stimulus space. Thus, GRS provides a framework for exploratory analysis of cortical functional organization in which regional boundaries are unknown and stimulus preferences are unclear.

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33.4069 Multivariate patterns of fMRI activity in human V2 predict the misbinding of color and motion

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Integrating visual features into objects correctly, known as the binding problem, is a fundamental challenge for the visual system. Here, we used the steady-state misbinding of color and motion (Wu et al., 2004) and fMRI MVPA to explore the neural mechanisms of active feature binding. The stimulus contained two sheets of random dots, one sheet moving up and the other moving down. On both sheets, dots in the right-end area and those in the rest area were rendered in different colors (red or green). When subjects fixated at the center of the stimulus, the color and motion of the dots in the right-end area were perceived to be bound in the same (i.e., misbinding state) or opposite (i.e., correct binding state) fashions as those in the rest area. During each fMRI run, subjects fixated at the center of the stimulus presented continuously for 180s and pressed one of two buttons to indicate their perceptual states, either the misbinding or the correct binding state. We trained a linear classifier to distinguish the multivariate patterns of BOLD response to these two perceptual states. Our results showed that the two states could be accurately decoded from the multivariate patterns as early as in V2. V4 and MT+ also showed performance above chance level. Furthermore, we trained another classifier with the multivariate patterns of responses to two physical (correct) binding stimuli (on each sheet, dots were rendered in the same color). We used the patterns responding to the misbinding states as the test data and found that only the patterns in V2 that encoded the physical binding predicted subjects' perceptual states, suggesting that the perceived misbinding stimuli were processed similarly to the physical correct binding stimuli in V2. These findings provide new evidence for the active binding of color and motion in human V2.

33.4070 Probing bimodal neural mechanisms in human ventral visual cortex

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Does perception of natural sounds probe category selective ventral temporal cortex VTC in the same way as visual stimuli do, or are other mechanisms involved? Here we investigate if cross-decoding between auditory and visual modalities is possible from neural responses in VTC. We hypothesize that natural sounds from a given category can predict the neural response to visual stimuli from the same category and vice versa. In a 3T MRI-scanner, subjects (n=18) were presented with 4 categories: face, body, scene, and object. These categories were presented in 4 auditory and 4 visual runs, repeating each category 4 times per run. For each pair-wise combination of conditions, we trained an SVM-classifier on multi-voxel patterns in the visual or auditory trials in VTC, and assessed the prediction accuracy using independent auditory or visual trials, testing all within/cross modality combinations. Across subjects, the visual to visual decoding was nearly perfect for all conditions pairs (Wilcoxon test, range of means across pairs: μ = [96.9-99.7%], p(FDR-corr) < 0.005). Auditory to auditory was significant for all but [body vs object], (μ = [58.6-59.8%], p(FDR-corr) < 0.05). Auditory to visual was significant for all pairs (μ = [62.5-76.0%], p(FDR-corr) < 0.01), and visual to auditory significant for all but [body vs face] and [scene vs object], (μ = [53.9-58.0%], p(FDR-corr) < 0.05). Strikingly, the across-modality generalization was asymmetric, being significantly better for auditory-to-visual than for visual-to-auditory ($p < 0.001$). Our results show not only that auditory stimuli elicit a distinctive response in VTC, but also that to a large extent we could cross-decode across modalities. This indicates that the neural responses in VTC to sound categories at least partially rely on the same neural mechanisms as with visual stimulation.

Acknowledgement: ERC

33.4071 A fully computable model of bottom-up and top-down processing in high-level visual cortex

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Specific regions of ventral temporal cortex (VTC) appear to be specialized for the representation of certain visual categories: for example, the visual word form area (VWFA) for words and the fusiform face area (FFA) for faces. However, a computational understanding of how these regions process visual inputs is lacking. Here we develop a fully computable model of responses in VWFA and FFA. We measured BOLD responses in these regions to a wide range of carefully controlled grayscale images while subjects performed different tasks (fixation task: judge color of a small central dot; categorization task: report perceived stimulus category; one-back task: detect image repetitions). Using cross-validation to control for overfitting, we developed a model that accurately accounts for the observed data. The first component of the model is a two-stage cascade of visual processing in which the bottom-up response in VTC (fixation task) is computed as the degree to which low-level stimulus properties match a category template. This reveals how high-level representations are constructed from simple stimulus properties. The second component of the model addresses top-down enhancement of VTC responses produced by performance of a task on the stimulus (categorization and one-back tasks). We show that the enhancement is stimulus-specific and can be modeled as a scaling of the bottom-up representation by the intraparietal sulcus (IPS). The third and final component of the model shows that the IPS response to a given stimulus reflects perceptual decision-making and can be quantitatively predicted using a drift diffusion model. Thus, the top-down scaling induced by the IPS is directly related to the behavioral goals of the subject. In sum, these results provide a unifying account of neural processing in VTC in the form of a model that addresses both bottom-up and top-down effects and quantitatively predicts VTC responses.

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33.4072 **Neural evidence for visual routines: transforming object representations across physical changes** Emily Ward[1](amyunimus@gmail.com), Marvin Chun[1]; [1]Department of Psychology, Yale University

Are there general neural mechanisms that perform visual transformations across all objects, or are transformations highly specific to individual objects? For example, in watching two objects become larger, we can appreciate that both objects are undergoing the same kind of transformation, but is the underlying neural transformation the same or different? We developed a novel computational approach to reveal visual transformations in visual cortex. We hypothesized that it should be possible to compute a mathematical transformation matrix that links object representations before and after physical change. If this represents a general mechanism, then when applied to a new object, the transformation matrix should yield a predicted representation that is consistent with the actual object representation after the physical change. We scanned 14 participants who viewed three different objects undergoing five different physical changes (enlargement, reduction, left-rotation, right-rotation, no-change). We measured activity patterns evoked by the objects in lateral occipital cortex before and after the physical change. Using regularized linear regression, we then predicted the response in each voxel in the post-change pattern from the response in all voxels in the initial pre-change pattern. Computing all regressions on training runs yielded a transformation matrix that was applied to the pre-change pattern in a test run of either 1) an unseen instance of the same object or 2) a new object. We compared the predicted post-change patterns to the true post-change patterns. We found that these transformation matrices produced post-change patterns that matched the true post-change patterns for unseen instances of the same object ($p< 0.001$). Critically, these transformation matrices generalized to new objects undergoing the same physical change ($p< 0.001$), suggesting that these transformations are abstract to some extent. These results demonstrate neural evidence for visual routines and show that such routines can be measured with fMRI.

33.4073 **Visual features versus categories: Explaining object representations in primate IT and deep neural networks with weighted representational modeling** Kamila Jozwik[1,2](jozwik.kamila@gmail.com), Nikolaus Kriegeskorte[2], Radoslaw Cichy[3], Marieke Mur[2]; [1]University of Cambridge, [2]Medical Research Council Brain and Cognition Unit, [3]Free University Berlin, Department of Education and Psychology

Visual features and category membership are both reflected in the object representation in inferior temporal (IT) cortex. However, the explanatory power of features and categories has not been directly compared. We test whether the IT object representation, in human and monkey, is best explained by a feature-based or a categorical model. We apply the same test to the object representations in a deep convolutional neural network (CNN). Previous work has shown that late layers of the network outperform early layers in explaining the human IT object representation (Khaligh-Razavi & Kriegeskorte 2014; Guclu & van Gerven 2015). We asked human observers to generate category labels (e.g. face, animal) and feature labels (e.g. eye, circular) for a set of 96 real-world object images. This resulted in rich models (> 100 dimensions), which we fitted to the brain and CNN representations using non-negative least squares. The brain representations of the 96 images were previously measured using fMRI (humans) and cell recordings (monkeys). Model performance was estimated on held-out images not used in fitting, and compared using representational similarity analysis. In both human and monkey, the feature-based and categorical model explain significant, and similar, amounts of IT variance (Fig. 1AB). Combining the two models does not explain significant additional variance, indicating that it is the shared model variance (features correlated with categories, categories correlated with features) that best explains primate IT. Consistent with previous findings, late layers of the deep neural network show a pattern of results similar to IT, while early layers are dominated by visual features (Fig. 1C). These results suggest that primate IT, as well as a deep neural network trained on image categorization, use visual features, including object parts that have stereotyped shapes and are strongly associated with particular categories, as stepping stones toward semantics.

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33.4074 **fMRI reveals different activation patterns for real objects vs. photographs of objects** Jacqueline Snow[1](jacqueline.c.snow@gmail.com), Scott Squires[2], Kevin Stubbs[2], Jody Culham[2,3]; [1]Department of Psychology, The University of Nevada, Reno, Nevada, USA, [2]Brain and Mind Institute, University of Western Ontario, London, Ontario, Canada, [3]Department of Psychology, University of Western Ontario, London, Ontario, Canada

Hundreds of functional magnetic resonance imaging (fMRI) experiments have revealed the neural substrates of object processing using photos of objects. Here we used univariate and multivariate pattern analysis (MVPA) of fMRI responses to determine whether photos are represented similarly to real objects in the human brain. The stimuli were everyday objects of comparable size and elongation. The photos were matched closely to the real objects for size and viewpoint. The stimuli were presented in rapid succession in the fMRI scanner using a custom-designed conveyor belt. We used a block design in which subjects viewed four exemplars (of different color, form, etc.) of one object type (e.g., whisks) in either real or photo format in each block. Univariate subtraction analysis revealed higher activation for real objects than photos in object-selective areas of the ventral visual stream (including the middle temporal gyrus, lateral occipital cortex, and fusiform gyrus) and dorsally in primary somatosensory cortex. Surprisingly, whole-brain searchlight representational similarity analysis showed that the lateral occipitotemporal cortex (LOTC) and anterior intraparietal sulcus (aIPS) were sensitive to the format in which stimuli were viewed, with stronger correlations for stimuli displayed in the same (i.e., Real-Real or Photo-Photo) versus different (i.e., Real-Photo) viewing dimensions. Finally, multidimensional scaling within independently-defined volumes of interest in left LOTC and aIPS revealed a global grouping that reflected a categorical distinction between real object and image displays, with more distinct representations for the real object exemplars than the images. Taken together, our results indicate that the human brain does not treat photographs as being equivalent to real objects. Real objects might elicit different brain-based responses to photos because they provide richer visual information, they have definite haptic qualities, and they afford genuine action.

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33.4075 **Effect of Attention on Object Responses in Human Parietal and Occipital-temporal Cortices: Similarities and Differences** Maryam Vaziri-Pashkam[1](mvaziri.p@gmail.com), Yaoda Xu[1]; [1]Vision Sciences Laboratory, Department of Psychology, Harvard University

Both human occipito-temporal and parietal cortices exhibit strong attentional effects as well as robust object representations. To understand how attention may interact with object representations, here we examined fMRI response patterns in topographic and functionally defined regions in occipito-temporal and parietal cortices to images of eight object categories under different attentional tasks. Participants viewed a sequential presentation of 10 exemplars of each object category, with each exemplar paired with a color, and performed a one-back repetition detection on either the objects or the colors. Using SVM classifiers, we examined the effect of attentional modulations 1) by comparing object classification when participants attended to object to that when they attended to color, and 2) by classifying the same objects across the two attentional tasks. In Experiment 1 colored dots were superimposed on uncolored objects. In both occipito-temporal and parietal regions object classification accuracy was higher when participants attended to objects than colors. Thus diverting attention away from the objects degraded object responses. A significant classification of the attentional tasks was also observed in these regions. This could reflect the degradation of object responses in the color task and/or a difference between the representations for the two attentional tasks. In Experiment 2 color appeared directly on the objects. None of the occipito-temporal and parietal regions examined showed a difference in object classification across the two attentional tasks, indicating automatic processing of all the features of an attended stimulus in an object-based manner. Interestingly, significant classification of the two attentional tasks was still observed in parietal but not in occipito-temporal regions. A representational similarity analysis further confirmed the results of the two experiments, showing that orthogonal representations for objects and attentional tasks can co-exist in parietal regions, but attentional effects only appear through modulations of object representations in occipito-temporal regions.

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33.4076 Lateral occipito-temporal cortex involvement in haptic object recognition: evidence against mere visual imagery Lars Strother[1](lars@unr.edu), Zhiheng Zhou[1], Tutis Vilis[2], Jacqueline Snow[1]; [1]University of Nevada, Reno, [2]University of Western Ontario

Lateral occipito-temporal cortex (LOTC) participates in haptic object recognition but its role is controversial. We used fMRI to test whether or not its role is limited to visual imagery of object shape. Participants palpated recognizable objects using the right hand, with the hand positioned either to the right or left of the body midline. Position of fixation was varied across blocks, so that gaze direction was either straight ahead, to the left or to the right of body midline; palpated objects were always occluded from view. Our results showed that left LOTC was activated more strongly than right LOTC, even when participants palpated objects on the left side of the body, which suggests that LOTC represents objects with respect to the hand rather than side of body. LOTC activation was nevertheless modulated by side of palpation. Additionally, LOTC responses were modulated by gaze direction—the strongest activation was observed when the location of the object was consistent with the direction of gaze (but not visible), although LOTC lateralization did not depend on the visual field location of the object. In contrast, activation in early visual cortex was best predicted by the visual field location of the palpated object (even though the object was hidden from view). Finally, somatosensory cortex and LOTC showed somewhat similar fMRI responses. If LOTC involvement in haptic object recognition reflects visual imagery, then LOTC lateralization should parallel that of early visual cortex. On the contrary, our findings suggest that LOTC encodes haptic shape cues in a hand-centered rather than body-centered coordinate frame, and thus LOTC activation during haptic object recognition is not indicative of potentially epiphenomenal visual imagery.

33.4077 Perceptual Experience and the Perirhinal Cortex D. Merika Wilson[1](dmerikawilso@umass.edu), David Ross[1], Lok Kin Yeung[2], Morgan Barense[2], Rosemary Cowell[1]; [1]University of Massachusetts, Amherst, [2]University of Toronto

We examined the effect of perceptual experience on visual representations in human cortex. Perirhinal cortex lies at the anterior end of the ventral visual stream and is thought to store complex representations of whole objects. One theory of perirhinal cortex function claims that it is important for discriminating highly similar objects that share simple visual features, and there is evidence to support this claim. However, it is not known how perceptual experience shapes and influences the object representations in perirhinal cortex. We examined the effect of short-term perceptual experience (i.e., seeing many objects from the same category over the course of a few minutes) on visual representations throughout the ventral visual stream and perirhinal cortex. Participants in the scanner viewed series of objects from the same category (e.g., teapots, shoes) while performing a 1-back repetition-detection task. In each series, individual object images were presented three times each, such that on the first presentation the object was novel and on the third presentation it was familiar. The difference in hemodynamic responses elicited by the first and third presentations –i.e., response adaptation– indicated whether a cortical region represented individual objects uniquely. In perirhinal cortex, individual stimuli for which the first and third presentations appeared early on in the series elicited significantly less response adaptation than stimuli for which the first and third presentations appeared in the last part of the series (i.e., after viewing a stream of objects from that category). We did not find this effect in regions of the ventral visual stream posterior to perirhinal cortex (i.e., lateral occipital complex). This result suggests that representations in perirhinal cortex become more specific to individual exemplars of an object category after experience with that category. This may be an effect of learning to attend to combinations of features that permit within-category discriminations.

Scene Perception: Neural mechanisms

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4078 A Data Driven Analysis Reveals the Importance of Image Properties in the Neural Representation of Scenes Timothy Andrews[1](timothy.andrews@york.ac.uk), David Watson[1], Tom Hartley[1]; [1]Department of Psychology, University of York, UK

The neural representation of scenes in human visual cortex has been linked to processing of semantic and categorical properties (e.g. categorization of indoor versus outdoor scenes). However, it is not clear whether patterns of neural response in these regions reflect more fundamental visual principles like those that govern the organization of early visual cortex. One problem is that existing studies have involved comparisons between stimulus categories chosen by the experimenter, potentially obscuring the contribution of more basic visual features. Here, we used a data-driven analysis to select clusters of scenes based solely on their image properties. Although these visually-defined clusters did not correspond to conventional scene categories, we found they elicited distinct and reliable patterns of neural response, and that the relative similarity of the response patterns to different clusters could be predicted by the low-level properties of the images. Local semantic properties of the images failed to explain any additional variance in the neural responses of scene-selective regions beyond that explained by the image properties. However, we did find that participants' behavioural classification of the scenes was better predicted by local semantic properties than by image properties. These results suggest that image properties play an important part in governing patterns of response to scenes in high-level visual cortex and suggest that these patterns are at least partially dissociated from behavioural responses which are better explained in terms of local semantic content.

33.4079 Depth preferences of category-selective regions in human visual cortex Daniel Berman[1,2](berman.72@osu.edu), Nonie Finlayson[1,2], Julie Golomb[1,2]; [1]Department of Psychology, The Ohio State University, [2]Center for Cognitive and Brain Sciences

Multiple regions in the human brain are selectively tuned to process particular categories of visual stimuli, such as scenes, objects, faces, and bodies. These category-selective areas likely have differential sensitivities to other visual features besides these superordinate categories. For example, scene-selective parahippocampal place area (PPA) and occipital place area (OPA) have been demonstrated to prefer distal stimuli, while object-selective lateral occipital complex (LOC) prefers proximal stimuli (Amit, Mehoudar, Trope, & Yovel, 2012). Here we explore whether these category-selective regions also show a general depth preference for locations either in front of or behind the point of focus. We presented participants with patches of random dot motion in different peripheral locations in a blocked fMRI design. Participants viewed the stimuli through red-green anaglyph glasses, such that we could stimulate a given 2D location at different depths (either in front of or behind fixation). Contrasting activation for these front and back locations, we found no depth preference in LOC or fusiform face area (FFA), and a significant front-preference in extrastriate body area (EBA) and motion sensitive area MT+. Interestingly, we found a significant back-preference in PPA and OPA, with non-significant trends in the same direction in retrosplenial cortex (RSC). This preference of scene-selective areas for stimuli behind fixation is consistent with the notion that real-world scene perception involves processing of background information which often appears behind the focus of attention.

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33.4080 Anchoring predictions in scenes: Electrophysiological evidence for a hierarchical structure in scenes. Sage Boettcher[1](sage.boettcher@gmail.com), Melissa Vo[1]; [1]Scene Grammar Lab, Goethe University Frankfurt

Objects in real-world scenes follow a set of rules, "scene grammar", that allow us to interact with our environment with ease. However, the particulars behind this set of rules are not fully understood. We propose that scene grammar is hierarchically structured. As a testing hypothesis we will primarily differentiate between three unique levels: Scenes, anchor objects, and objects. Anchor objects are distinguishable from other objects in that they are generally large, salient, and diagnostic of a scene. More importantly, these objects serve as anchors for spatial predictions regarding many of the other objects in the scene (e.g. the pot is found on the stove, the soap is found in the shower) allowing for efficient object perception and search. Understanding the structure of scene grammar requires understanding of how these levels interact and work together. In an EEG experiment we asked participants to view two images presented one after another and determine if they were semantically congruent, or incongruent. Importantly, the first image, i.e. the prime, was either a scene (e.g. a kitchen) or a non-anchor object (e.g. a pan). The second image was always an anchor object either consistent (a stove) or inconsistent (a shower) with the prime. The N400 ERP component — originally known from language processing — signals semantic integration costs. Therefore, if the prime activates semantic predictions regarding the anchor we would expect violations of such semantic expectations to result in an increased N400 in response to the onset of the anchor. Moreover, the stronger the predictions activated by the prime, the greater the N400. Interestingly, we found a larger N400 for the anchor when observers were initially primed with non-anchor objects compared to scenes. This indicates that objects generate stronger predictions of anchors compared to the scenes which anchors are contained in.

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33.4081 **Neural Representation of the Horizontal Extent of Spatial Boundary Cues** Ruu Harn Cheng[1](rhcannie@gmail.com), Katrina Ferrara[2], Soojin Park[1]; [1]Department of Cognitive Science, Johns Hopkins University, [2]Center for Brain Plasticity and Recovery, Georgetown University

Boundary cues are crucial for defining the spatial constraints of an environment. A recent neuroimaging study showed that the parahippocampal place area (PPA) is sensitive to the presence of vertical boundary structure in scenes (Ferrara & Park, 2014). On the other hand, developmental research suggests that not all environmental structures can serve as effective spatial boundaries: four-year-old children can geometrically reorient by a continuous curb that is only 2cm in vertical height, but fail to do so by tall, isolated columns connected together by a string (Lee & Spelke, 2011). Such results call attention to the potential importance of the horizontal continuity of a spatial boundary, yet little is known about whether scene-selective brain regions are sensitive to spatial boundaries that vary in this respect. In the current study, we manipulated the horizontal continuity of boundaries by varying the amount of poles included in artificial scene images. There were 6 conditions (see Supplemental Figure): no boundary (0 poles, open field), 3 poles, 9 poles, 17 poles, 33 poles, and 65 poles (wall). Participants (N=6) viewed these conditions in blocks of 12 seconds while performing a one-back repetition task. We measured univariate and multivoxel pattern activity in the PPA, a region known to respond to scene geometry. Preliminary results suggest that, contrary to its acute sensitivity to the vertical height of boundaries, the PPA is relatively insensitive to horizontal solidity of a boundary. Both univariate and multivoxel activity suggest that the PPA is sensitive to the presence of vertical poles in a scene (e.g., open field vs. a scene with 3 poles (p=.029)), but not to variations in the number of poles (3 poles – 65 poles), despite the striking low-level visual differences across these conditions. These results provide insight to which specific geometric features constitute the PPA's representation of scene geometry.

33.4082 **Neural Sensitivity to Boundary Cues Across Different Scene Geometries** Katrina Ferrara[1](katrina.ferrara@gmail.com), Ruu Harn Cheng[2], Soojin Park[2]; [1]Center for Brain Plasticity and Recovery, Georgetown University, [2]Department of Cognitive Science, Johns Hopkins University

Boundary cues crucially contribute to the spatial layout of an environment. Developmental research highlights the importance of vertically extended structure in defining the geometry of space: four-year-old children fail to reorient themselves in an arena marked by a flat black mat, whereas they can do so by a 3D curb that is only 2 cm in height (Lee & Spelke, 2011). Consistent with this finding, a recent neuroimaging study demonstrated that the parahippocampal place area (PPA) is sensitive to the presence of 3D vertical boundary structure, even if this structure is quite minimal (a "curb" boundary) (Ferrara & Park, 2014). Here, we ask whether PPA's sensitivity to the vertical height of spatial boundary cues would be affected by variation in scene geometry, specifically when manipulated by varying the amount of angular (rectilinear) information. In the current study, we used artificially created scenes that varied along 1) scene geometry (Triangle, Rectangle, Hexagon, Circle), and 2) height of boundary cue (Mat (2D boundary), Curb (~3 inches high), Wall (typical indoor space), see Supplemental Figure). Participants (N=5) viewed these conditions in blocks of 12 seconds while performing a one-back repetition task. We measured the univariate response of scene-selective regions. Consistent with the findings of Ferrara & Park (2014), right PPA shows differences in activity between the Mat and Curb across all scene geometry conditions. Moreover, neither a main effect of scene geometry nor an interaction between that and boundary height were found. These findings suggest that PPA's sensitivity to the minimal vertical structure of the Curb extends across environments of many different spatial geometries. Thus, its sensitivity to minimal vertical boundary structure is not modulated by the amount of rectilinear information that is included in a boundary. Results of extended scene-selective cortical areas (RSC and TOS) will be also discussed.

33.4083 **Neural Substrates of Camouflage-Breaking** Jay Hegdé[1,2,3], Donatello Arienzo[1,4]; [1]Brain and Behavior Discovery Institute, Augusta University, Augusta, GA, [2]James and Jean Culver Vision Discovery Institute, Augusta University, Augusta, GA, [3]Department of Ophthalmology, Medical College of Georgia, Augusta University, Augusta, GA, [4]Psychiatry and Health Behavior, Medical College of Georgia, Augusta University, Augusta, GA

Recognizing an object camouflaged against its background, or camouflage-breaking, can be a matter of life or death in nature. It is also fundamentally important in warfare and game hunting. The neural mechanisms of camouflage-breaking remain unclear. We measured the neural responses of human subjects using functional magnetic resonance imaging (fMRI) while the subjects (N = 22) freely searched the camouflage scene and reported whether or not a camouflaged target object, such as a human face, was present in the scene. Using an analysis of variance (ANOVA) design, we identified 29 cortical and sub-cortical regions of interest (ROIs) that showed highly significant differential responses during the camouflage-breaking task (p < 10-9, corrected for multiple comparisons). The differential neural responses were not attributable to eye movements in any ROI (partial F tests; F [1,12] < 0.01, p > 0.05 in all cases). Neural activity in 6 of the ROIs in the occipito-temporal pathway were collectively diagnostic of successful camouflage-breaking on a trial-to-trial basis, as determined by multi-voxel pattern analysis (MVPA; class accuracy, 0.73; area under the ROC curve, 0.74; p < 0.05). Multivariate Granger Causality analysis of the network connectivity identified 129 highly significant pairwise, directional connections during 'hit' trials wherein the subjects correctly reported that the scene contained a camouflaged target (p < 10-9, corrected). The pattern of network connectivity was significantly different when the subjects failed to detect the target ('miss' trials; quadratic assignment procedure [QAP], p < 10-6). A separate control experiment (N = 4) showed that the aforementioned network connectivity patterns during camouflaged-breaking were significantly different than those during conventional visual search, in which the subjects reported whether a non-camouflaged 'odd-man-out' face target was present among non-camouflaged distractor faces (QAP, p < 10-6). Together, our results characterize, for the first time, the brain regions that subserve camouflage-breaking.

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33.4084 **Understanding visual scenes: a combined MEG and eye-tracking study** Linda Henriksson[1,2](linda.henriksson@aalto.fi), Kaisu Ölander[1,2,3], Riitta Hari[1,2]; [1]Department of Neuroscience and Biomedical Engineering, School of Science, Aalto University, Finland, [2]MEG Core, Aalto NeuroImaging, School of Science, Aalto University, Finland, [3]Current address: Institute of Behavioural Sciences, Division of Cognitive and Neuropsychology, University of Helsinki, Finland

Natural visual scenes are rich in information, and scanning eye movements are needed to gather this information. But how do we select where to look next? Previous studies suggest that faces attract especially effectively attention and saccades (Yarbus, 1967; Crouzet et al., 2010). In this combined magnetoencephalography (MEG) and eye-tracking study, we aimed to identify the saccade and brain dynamics underlying target selection during free viewing of natural scenes. The stimuli were 199 grayscale photographs of natural scenes, including landscapes, scenes with a single person, and cluttered scenes with several persons presented for 1 s at 6.3–7.1 s inter-stimulus intervals. The subjects (N = 18) were instructed to fixate a cross at the centre of the screen before the stimulus onset, and to look freely at the images when they appeared. Each stimulus was followed by a question about its content (e.g., 'Was there water?'). We applied representational similarity analysis (RSA; Kriegeskorte et al., 2008) to study the MEG responses and to relate the MEG and eye-tracking results. From ~50 ms after stimulus onset, the similarity of the MEG responses correlated with the low-level similarity of the images, indicating that the evoked single-trial MEG responses contained information about the natural-scene stimuli. At later latencies, but before the onset of the first saccade, the similarity of the MEG responses correlated also with the target of the first saccade and with the upcoming scan-path of eye movements. These results suggest that combining MEG with eye tracking can inform about the cortical dynamics of visual-scene understanding.

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33.4085 **Context-Based Predictions and Errors in Scene-Selective Cortex** Robert Wiley[1](wiley@cogsci.jhu.edu), Soojin Park[1]; [1]Johns Hopkins University

How a scene is represented is inextricably tied to its spatial and temporal context. When we navigate in the world, we build expectations about one view leading to the next. Previous work has found representations of visual scenes in scene-selective cortex (parahippocampal place area,

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PPA) depend on temporal context. Specifically, repetition suppression for repeated scenes was greater when they appeared after the same previously encountered temporal context than for scenes appearing after a novel context. In this study, we ask whether representation of a scene's context is tied to the level of the exemplar, or whether it is encoded more flexibly, at the abstract level of the scene category. To test this, we use the repetition suppression paradigm. During fMRI, participants (ages 18-27, n = 18) viewed a stream of scenes while performing an indoor/outdoor decision task. The temporal context was generated by repeating 'triplets' of scenes (e.g., ForestA-FieldA-KitchenA). There were three temporal context conditions—Novel: third item repeated preceded by novel items (e.g., OfficeA-HighwayA-KitchenA), Repeated-Exemplar: all three exemplars of a triplet repeated (e.g., ForestA-FieldA-KitchenA), or Repeated-Category: third item repeated preceded by new exemplars of repeated categories (e.g., ForestB-FieldB-KitchenA). We found significant repetition suppression for Repeated-Exemplar and Novel conditions in posterior PPA, but not anterior PPA. Moreover, we found significant repetition enhancement for the Repeated-Category condition in retrosplenial cortex (RSC). We propose that the repetition enhancement in RSC reflects the prediction error arising from a mismatch between prediction and stimulus presentation in the Repeated-Category condition. Current results suggest that neural response of scene-selective cortex is sensitive to temporal predictions made at multiple levels, and especially to the mismatch of the prediction and the stimulus presented at any level. Such sensitivity may help distinguish scenes with similar views from different places that have different navigational context.

33.4086 **Semantic inconsistencies without semantics? Semantically inconsistent objects elicit N400 responses on both real-world and apparently meaningless synthesized scenes** Tim Lauer[1](lauer-tim@stud.uni-frankfurt.de), Tim Cornelissen[1], Melissa Vo[1]; [1]Scene Grammar Lab, Goethe University Frankfurt

Viewing objects that are semantically inconsistent with the scene they are embedded in — like a toaster on the beach — elicits ERPs with a parietal negativity that peak about 400 ms after scene onset and typically reflect semantic violations. What information of the scene context is sufficient to trigger an N400 response? To answer this question, we created a synthesized texture for each scene with identical summary statistics but without any obvious semantic meaning. We then presented objects on either images of scenes, their texture versions, or a scrambled control background that maintained the colors of the image, but no higher-order statistics, resulting in three types of backgrounds: Real-world scenes, textures, and controls. To create semantic inconsistencies, we paired indoor and outdoor scenes with either a consistent or an inconsistent object thumbnail. The object was centered on the background and both were presented simultaneously. We found a parietal negativity in the N400 time window (350-600 ms) for consistent versus inconsistent objects on real-world scenes. Interestingly, objects on inconsistent texture backgrounds also elicited an N400 response with a similar time-course and topography, though less pronounced. The control condition, however, showed no such response. These results first of all replicate previous findings of N400 responses to semantically inconsistent objects in scenes. More importantly, our data suggest that the mere presentation of the summary statistics of a scene is sufficient to lead to integration costs of objects that are semantically inconsistent with their scene context. These costs are reflected in a less pronounced, yet substantial N400 response compared to real-world scenes. Future electrophysiological and/or behavioral investigations may replicate these preliminary findings and clarify the role of summary statistics for the semantic integration during object and scene processing.

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33.4087 **Distinct neural and cognitive systems selectively involved in navigation and categorization of scenes** Andrew Persichetti[1](apersic@emory.edu), Samuel Weiller[1], Alex Zorn[1], Kevin Williams[1], Daniel Dilks[1]; [1]Department of Psychology, Emory University

Recent work has suggested that visual scene processing is composed of two distinct systems: one for navigation, including the occipital place area (OPA) and retrosplenial complex (RSC), and the other for scene categorization (e.g., recognizing a scene as a kitchen), including the parahippocampal place area (PPA). If scene processing is indeed composed of these two systems, then it should be possible to selectively modulate the two systems by changing task demands to reflect their functions. Thus, we used fMRI to test our prediction that PPA would respond more to an image of a scene when a viewer was performing a 'categorization' task on an image than when the same viewer was performing a 'navigation' task on the exact same image, while OPA and RSC would show the opposite pattern. Crucially, both tasks were completed on the exact same stimuli, behavioral performance was matched between tasks, and participants were required to fixate during both tasks, ensuring that any neural differences between tasks were not due to low-level visual stimuli differences, differences in task difficulty, or differences in eye movements. As predicted, we found that PPA responded significantly more during the categorization than navigation task, while OPA showed the opposite pattern. Interestingly, however, RSC responded similarly to both tasks. In a second experiment conducted outside of the scanner, we used eye tracking in a separate group of participants to further test our two-systems-for-scene-processing hypothesis. The design of this experiment was similar to the first experiment in every way, except now the participants' eyes were free to wander. Consistent with our hypothesis, we found a different pattern of eye movements when participants performed a navigation task compared to a categorization task. Taken together, these results suggest distinct neural and cognitive systems selectively involved in navigation and categorization of scenes.

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33.4088 **Exploring spatio-temporal neural basis of scene processing with MEG/EEG using a convolutional neural network** Ying Yang[1,4](yingyan1@andrew.cmu.edu), Robert Kass[1,3,4], Michael Tarr[1,2], Elissa Aminoff[1,2]; [1]Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Psychology Department, Carnegie Mellon University, [3]Department of Statistics, Carnegie Mellon University, [4]Machine Learning Department, Carnegie Mellon University

Human brains can efficiently process rich information in visual scenes. The neural mechanisms underlying such proficiency may involve not only feedforward processing in the hierarchical visual cortex, but also top-down feedback. To understand these mechanisms, we explored the nature of the visual scene features processed at different brain locations and different time points using high-temporal-resolution MEG and EEG - in separate sessions - while participants viewed briefly presented (200ms) photographs of scenes. We used linear regression to quantify the correlations between neural signals and visual features of the same images, where these features were derived from a convolutional neural network (CNN) with 8 hierarchically organized layers. Next we tested whether variance in the neural signals was explained at each time point and each location by features in different layers, thereby creating a spatio-temporal profile describing the significance of correlation with different CNN layers. For both the MEG and EEG sensor data, we observed that the majority of layers exhibited significant correlations from 60~450 ms after the stimulus onset. When contrasting low-level Layer1 with higher-level Layer6, we found that Layer1 demonstrated greater significance early on (before 120 ms), while Layer6 showed greater significance somewhat later (after 150 ms). In a preliminary analysis of source localized MEG data, we again observed sustained significance for the majority of layers, as well as early greater significance of Layer1 in lower-level visual cortex and later greater significance of Layer6 in higher-level visual cortex. This early to late, lower- to higher-level progression indicates feedforward information flow. Additionally, the sustained significance of low- and high-level layers, which was maintained until at least 400 ms, indicates possible non-feedforward neural responses during scene processing. We are also using connectivity analysis to further investigate if there is top-down feedback from frontal lobe and inferior temporal lobe to the visual cortex.

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33.4089 **Continuity fields revealed by attention-based serial dependence in fMRI BOLD responses** Ye Xia[1](yexia@berkeley.edu), Karl Zipser[2], David Whitney[1]; [1]Department of Psychology, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley

Object identities appear stable despite their constantly changing image properties. This may reflect a Continuity Field, a mechanism of perceptual stability built on serial dependence, in which objects appear more similar over time than they actually are. Although explored in psychophysics, the physiological basis of perceptual serial dependence and the Continuity Field are unknown. Here, we used fMRI to test whether responses in early visual areas are biased toward previous stimuli in an attention-dependent

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manner. Subjects viewed natural movie segments (fixating) while performing three different tasks in separate runs. The three tasks were free attending, during which the subject reported attending to the main character in the video, attending to the supporting (not main) characters, and attending to the background scene. We correlated the BOLD signal of one task with the BOLD signal of another task (used as a reference signal) shifted back from one to five TRs (TR = 900 ms). We computed correlation coefficients of the BOLD signals of the tasks with their respective reference signals. These coefficients quantify the serial dependence effect and the autocorrelation of the stimuli. Taking the difference of two such correlation coefficients cancels out the autocorrelation and factors out the temporal blurring of the hemodynamic response, thus revealing the difference of the serial dependence effect between two tasks. Since perceptual serial dependence is modulated by attention, we expected more serial dependence in the BOLD signal for face specific regions during the attend-to-face tasks. Our results show this expected difference, and this difference was significantly higher for the attended face than for the non-attended faces. These results suggest that the activity of the voxels in early visual areas are biased toward previously attended stimuli in a spatially selective manner, hinting at a physiological basis for the continuity field and the resulting perceptual serial dependence.

33.4090 Scene selectivity and retinotopy in medial parietal cortex

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Functional imaging studies in human reliably identify a trio of scene-selective regions, one on each of the lateral (occipital place area, OPA), ventral (parahippocampal place araea, PPA) and medial (retrosplenial complex, RSC) cortical surfaces. Whilst the basic selectivity, and more recently retinotopic organization of OPA and PPA are relatively well understood, much less is known about the medial scene-selective area. Here, using fMRI, we combine detailed mapping of both population receptive fields (pRF) and category-selectivity, with independently acquired resting-state functional connectivity data, to examine retinotopic sensitivity within medial scene-selective cortex across a large number of participants. Consistent with previous work, we identify a medial scene-selective area, which was largely contained within the posterior bank of the parieto-occipital sulcus (POS) and did not extend into restrosplenial cortex, suggesting the use of RSC as a label for this region is potentially misleading. Interestingly, this same region was identifiable solely on the basis of responses to our retinotopic mapping stimuli with a striking degree of spatial consistency across participants. Our pRF analyses of this region not only demonstrate a high degree of retinotopic sensitivity, but also, highlight a significant contralateral visual field bias, coupled with very large receptive fields. Unlike, its scene-selective counterparts OPA and PPA, this medial scene-selective region did not show a consistent bias to either the lower or upper visual fields, respectively. The contralateral representation within this region was also confirmed through functional connectivity patterns observed in our independent resting-state data. Further, this medial scene-selective area appears to show greater connectivity at rest with anterior portions of ventral PPA than lateral OPA, despite lacking the upper visual field bias exhibited by PPA. Taken together, the retinotopic profile of medial scene-selective cortex suggests a prominent role in mediating scene related visual information between lateral OPA and ventral PPA.

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33.4091 Cortical feedback to V1 and V2 contains unique information about high-level scene structure

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Neurons in early visual cortex receive highly selective feedforward input that is amplified or disamplified by contextual feedback and lateral connections (Phillips, 2015; Gilbert & Li, 2013). Many cortical areas feed back to early visual cortex, yet measuring feedback channels presents a central challenge to fully understanding neural computations (Muckli & Petro, 2013). To isolate feedback we blocked feedforward input to subsections of retinotopic visual cortex with a uniform visual occluder covering one quarter of the visual field (Smith and Muckli, 2010) while participants viewed 24 real-world scenes. Scenes spanned six categories and two spatial depths, allowing us to investigate whether feedback contains information about these features. By using pattern classification techniques we found that response patterns in occluded subsections of V1 and V2 contain individual scene, category and depth information, and that category information was generalizable across scenes while depth information was not (Figure 1). Feedback to early visual cortex is therefore specific to individual scenes while concurrently conveying some high-level structure. Still, occluded V1 and V2 responses differed from each other, suggesting that feedback to these two areas has unique information content (Figures 2 & 3). Finally, V1 and V2 represented scenes differently than three popular biologically-inspired computational models (Weibull, Gist, and H-MAX; Figure 3). Together, these results suggest that in order to understand neural computations of early visual cortex, we must understand the contribution of cortical feedback.

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33.4092 Using SSVEPs to measure brain responses of chronic cannabis users and nonusers to during a visual recognition task

Brandi Emerick[1](brlemeri@indiana.edu), Tom Busey[1], Brian O'Donnell[1]; [1]Department of Psychological and Brain Sciences, Indiana University

Much of the previous research on the effects of cannabis has focused on memory and executive function. Less is known about how cannabis affects visual perception. However, there are cannabinoid receptors in the retina, thalamus, and visual cortex (Schwitzer et al., 2014), and cannabis users frequently report changes in sensory perception (Green, Kavanagh, & Young, 2003). To determine whether chronic cannabis use affects how individuals attend to and recognize images, we used EEG to record steady-state visual evoked potentials (SSVEPs) during a visual recognition task. Images were degraded using Photoshop and embedded within visual noise to make recognition challenging. Two presentation frequencies were used to frequency-tag image and noise, allowing us to track the strength of brain responses to image and noise separately throughout recognition, despite image and noise being superimposed. In half the trials, images were flickered at 6.67 Hz and noise at 8.57 Hz, and image and noise were presented at 8.57 Hz and 6.67 Hz, respectively, for the other half. Participants were instructed to press a button once they recognized the image and to do their best to attend to images and ignore noise during the entire trial. Chronic cannabis users and nonusers showed qualitatively similar responses: SSVEPs to image and noise were typically greater after the image was recognized, and responses to image were generally stronger than responses to noise (likely due to the instruction to attend to image and ignore noise). However, SSVEPs recorded from chronic users were weaker than the responses from nonusers in many cases. Also, the difference between response strength for image versus noise was sometimes greater for nonusers. Results suggest that chronic cannabis use may affect one's ability to ignore noise and attend selectively to images, but this is somewhat dependent on presentation frequency and electrode location.

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Perceptual Learning: Adaptation

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4093 Event-related potential measurements of long-term orientation specific adaptation

Yihwa Baek[1](baekx055@umn.edu), Stephen Engel[1]; [1]Department of Psychology, College of Liberal Arts, University of Minnesota

Exposure to a new environment elicits changes that keep vision functioning well. Adaptation occurs at various time scales, with some effects arising after only a few milliseconds and others growing slowly over hours or days. Long-term adaptation has been measured in prior behavioral work. However, its neural bases are as of yet unknown. We filled this gap, by measuring long-term adaptation with event-related potentials (ERP). We induced a form of contrast adaptation by placing subjects in a vertically-deprived environment. Subjects wore virtual reality goggles that showed video from a head-mounted camera. The images were filtered to reduce vertical energy by 85%. Subjects performed everyday activities while viewing the filtered world for 4 hours. Before and after adaptation, we measured ERP responses to vertical and horizontal circular 10 deg grating patches at 15% contrast. Stimuli randomly appeared in upper or lower visual fields and were interleaved with filtered "top-up" movie clips to maintain adaptation. Peaks in the ERP were observed at around 100 ms following stimulus presentation at posterior electrodes. To measure response amplitude, we averaged ERP voltages across 16 ms surrounding the peak. Prior to adaptation, response amplitudes were equal to both orientations. Immediately

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following adaptation, the responses were significantly different ($p < .05$). This effect of adaptation decayed during the 1-hour test period. It was also larger in the lower visual field than in the upper visual field. The simplest account of these results is that adaptation caused neurons tuned to vertical and horizontal to change their gain. Our data suggest that deprivation of vertical produced larger reductions in horizontally-tuned neurons' gain and smaller increases in vertically-tuned neurons', likely as a result of contrast normalization across orientations. Our results represent some of the first electrophysiological measurements of long-term adaptation in cortex.

33.4094 **Long-term face aftereffects are more robust following distributed adaptation** Thomas Ditye[1](thomas.ditye@gmail.com), Barbara Hiess[1], Marit Petzka[1], Claus-Christian Carbon[2], Ulrich Ansorge[1]; [1]Department of Basic Psychological Research and Research Methods, Faculty of Psychology, University of Vienna, [2]Department of General Psychology and Methodology, Institute of Psychology, University of Bamberg

Adaptation is an automatic neural mechanism to maximize sensitivity and efficiency of the visual system on the basis of previous experiences. The study of perceptual short-term effects of adaptation has a long tradition, but the mechanisms underlying long-term aftereffects are still poorly understood. Long-term aftereffects can last for days, weeks, and even months suggesting a significant role of adaptation in learning about the visual properties of the world. Here, we tested how the organization of different adaptation protocols affects the robustness of face distortion aftereffects along multiple time scales. In all experiments, adaptation to a distorted image of a famous person biased participants' perception of the original faces. The time taken to deadapt from this initial effect and the degree to which adaptation effects recovered following an interval without further adaptation were used as measure of the robustness of long-term effects. Long-term effects were more stable in groups of participants who adapted in a distributed fashion (10 × 1 min of adaptation over 1h) compared to a group of participants who underwent blocked adaptation (1 × 10 min over 1h). Data from measures of electrophysiology (i.e., EEG) complement the behavioral findings. These findings are in support of the claim that adaptation changes the neural representations of our environment also in a lasting manner. Furthermore, long-term effects are modulated by the temporal organization of adaptive experiences.

33.4095 **Visual Adaptation to Temporal Sequences** Nilufar Razmi[1](razmin881@mums.ac.ir); [1]Student Research Committee, Mashhad University of Medical Sciences, Mashhad, Iran

Sensory adaptation happens when a neuron responds less to a repetitive and unchanged quality of a stimulus. Well-known adaptation effects exist for signals that are linked together across space, such as objects and faces. Possible adaptation to different signals that are linked to each other in time has been a much less studied field. Here we studied orientation adaptation to oriented gratings in a sequence of three gratings that repeated in time. The stimuli consisted of three gratings (100ms each, 200ms between each grating in sequence, 600 ms between sequences). In pre-adaptation phase, the first two were tilted 15° to right (or left) and a near vertical test grating followed those. A familiar tilt aftereffect was found here where the test grating was repelled from the two preceding stimuli. In adaptation phase the stimuli were two gratings tilted 15° to right (or left) and the last one to 15° left (or right). Subjects (N=3) viewed repetitions of this sequence. After that, the same sequence of pre-adapt test was shown. Compared to pre-adapt responses, subjects showed a statistically significant aftereffect (-2.2°± 0.78 $p< 0.05$, 1.6°±0.36 $p< 0.01$) in the opposite direction, which was repellent to orientation of the last grating in adapting sequence rather than repellant to the immediately preceding stimuli of the test sequence. In a control group (N=3) the pre-adapt was the same and the adapting pattern consisted of the same number of stimuli as previous group adapting patterns but shown in random order. No significant aftereffect was observed (-0.34°±0.4 $p=0.2$, 1.2°±1.7 $p=0.2$). Therefore this temporal contextual modulation effect cannot be explained by simple averaging of signals that make up the adapting sequence. These results suggest that visual system is able to extract patterns not only across space, but also across time and adapt to them.

Acknowledgement: - Student Research Committee, Mashhad University of Medical Sciences, Mashhad, Iran

33.4096 **Habituation of visual adaptation** Xue Dong[1](dongx@psych.ac.cn), Yi Gao[1], Lili Lv[1], Min Bao[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences

Our sensory system adjusts its function driven by both shorter-term (e.g. adaptation) and longer-term (e.g. learning) experiences. Most past adaptation literature focuses on short-term adaptation. Only recently researchers have begun to investigate how adaptation changes over a span of days but reported mixed findings. However, this question is important, since in real life many environmental changes stretch over multiple days or longer. Here we addressed this issue by tracking perceptual bias (also known as aftereffect) induced by motion or contrast adaptation across multiple daily adaptation sessions when attention was focused on the adapters by a task or on the fixation. In the experiments of motion adaptation, dynamic motion aftereffect (dMAE), which was evaluated using nulling percentage (Blake, R. et al., 1993, Vision Res), was measured during top-up adaptation; static motion aftereffect (sMAE), which was evaluated using MAE duration, was measured after adaptation. In the experiments of contrast adaptation, the contrast thresholds before and after continuous adaptation were tracked using ramp detection method (Dong, X. et al., 2014, Perception). Aftereffects were measured every day which corresponded to the degree of adaptation on each day. Though the sMAE remained constant, which is consistent with previous study, dMAE and contrast adaptation effect showed similar general reduction after several days of repeated adaptation sessions. For passively viewed adapters, repeated adaptation attenuated aftereffects. Once adapters were presented with an attentional task, aftereffects could either reduce for easy tasks, or initially show an increase followed by a later decrease for demanding tasks. Quantitative analysis of the time for decay in contrast adaptation showed that repeated exposure of the adapter appeared to be equivalent to adaptation to a weaker stimulus. These results suggest that both attention and a non-attentional habituation-like mechanism jointly determine how adaptation develops across multiple daily sessions.

33.4097 **Still seeing straight: No role for ocular proprioception in prism adaptation?** Therese Gilligan[1](pspec3@bangor.ac.uk), Filipe Cristino[1], Robert Rafal[1], Janet Bultitude[2]; [1]School of Psychology, Bangor University, [2]School of Psychology, Bangor University, [3]School of Psychology, Bangor University, [4]Department of Psychology, University of Bath

Reaching toward a visual target displaced by laterally refracting prisms results in adaptation of limb proprioception and a visual shift, which individually and additively lead to prism adaptation (PA). The visual shift is hypothesised to be due to recalibration of neural signals encoding the straight ahead eye position in the orbit; itself hypothesised to be a result of error correction during PA, and to a contribution from 'eye muscle potentiation' (EMP) – a resetting of ocular straight ahead following sustained lateral gaze. This research is the first to directly investigate the contribution of ocular proprioception to PA by measuring eye position before, during, and after PA and also before, during, and after a condition in which gaze was shifted but no visual feedback of pointing errors were available (eye muscle proprioception; EMP). We also recorded measures of limb proprioception (straight-ahead pointing with eyes closed; SAP) and measures of combined ocular and limb proprioception (open-loop pointing; OLP) using eye tracking and touchscreen systems. Consistent with previous research, healthy participants (n=17) showed larger after-effects in OLP than SAP, after PA but not after EMP, consistent with the idea that PA results in a shift in the representation of visual targets. However, contrary to our hypothesis, there was a change in straight-ahead ocular fixation following the EMP condition, but not after PA. One interpretation of these results is that the PA-induced visual shift in the location of targets is not the direct result of recalibration of eye position in the orbit but may be more exclusively the result of adapted limb proprioception and a change in proprioceptive-spatial mapping against visuo-spatial mapping.

33.4098 **Repeated adaptation to natural images with biased orientation statistics does not alter adaptation dynamics** Juraj Mesik[1](mesik002@umn.edu), Akshay Patke[1], Stephen Engel[1]; [1]Department of Psychology, University of Minnesota

Despite our constantly changing environment, the visual system remains efficient through the process of visual adaptation. While this rapid form of neural plasticity has been widely studied, it remains unknown whether the rate at which it operates can change through experience. Here we addressed this question by repeatedly adapting subjects to naturalistic visual input with stereotypical orientation statistics, which we term a context. In 4 hours session on 3 consecutive days, subjects (n=8) viewed their surroundings via a head-mounted display with an attached camera, whose input was filtered so as to produce novel visual statistics. In each session, filtering alternated every 30 min between two visual contexts: One where contrasts of orientations around vertical were enhanced and contrast around horizontal was reduced, and one with the opposite pattern of filtering. Viewing inputs under both these conditions produced contrast adaptation, which we measured using the tilt-aftereffect (TAE), i.e. shifted perception of orientations near the adapted axes. To measure the TAE, subject completed 2.5 min blocks of trials where they viewed a plaid pattern (100 ms presentation with 2 sec ISI) consisting of +/- 45 deg gratings, and used the mouse to adjust the gratings' orientations until the plaid appeared to contain square checks. These measures were taken after 2 and 30 min of adaptation within each context, and were compared across days. Our paradigm induced robust TAE in both conditions (0.6 deg and 1.5 deg within the first 30 sec of the block, both p < 10-4), which decayed over the course of the block. However, comparison across days showed no significant changes in TAE magnitude or decay rates. These results suggest that the degree of familiarity with the statistical structure of visual environments does not alter the rate of visual adaptation, at least for the timescales and contexts tested here.

33.4099 **Changes in confidence judgments with perceptual aftereffects** Baptiste Caziot[1](baptiste.caziot@ens.fr), Pascal Mamassian[1]; [1]Laboratoire des Systemes Perceptifs, Departement d'Etudes Cognitives, Ecole Normale Superieure

Visual confidence refers to the ability to predict one's own performance. Thus for confidence to be useful, it must be well calibrated with performance. How then does confidence change when percepts are modified due to adaptation (aftereffects). Observers were instructed to estimate their confidence across 2 different perceptual tasks. In an orientation discrimination task, a 500ms series of Gabor adapters (10deg, 2cyc.deg-1, 50% contrast, random phase every 50ms), oriented -20, 0 or +20deg from vertical, was followed by a 100ms blank before a 100ms test target, oriented in 7 values from -2.1 to +2.1deg. Similarly, in a color discrimination task a 500ms adapter patch (10deg, high contrast black edge) with -0.75, 0 or +0.75 (green, gray or red) of the monitor maximum gamut along the "red/green" axis of the DKL colorspace was followed by a 100ms blank, then a 100ms test patch with a gamut ranging in 7 values from -0.35 to +0.35. Following a pair of orientation and color stimuli, whose order varied from block to block, observers were instructed to report in which of their 2 prior answers they felt more confident (most likely to be correct). Observers successfully switched between the two tasks and were able to make a confidence judgment across the two different visual modalities. Clear negative aftereffects were observed in both tasks (means > 1SD). Response times and confidence judgments were shifted by the adapters by about the same amount as the psychometric functions. Normal cumulative, probability density and inverse of the probability density functions were fitted to respectively performance, response times and confidence. Correlations on fit parameters normalized by SD were high (>0.7), with a regression slope of about 1, suggesting that confidence is mediated by the same mechanism that mediates perceptual reports and response times.

33.4100 **Effects of adaptation on orientation tuning in excitatory and inhibitory neurons in macaque V1 and V2** Daniel Thengone[1](dat2011@med.cornell.edu), Yunguo Yu[1], Jonathan Victor[1]; [1]Brain and Mind Research Institute, Weill Cornell Graduate School of Medical Sciences

Adaptation modifies sensory pathways to adjust to the characteristics of the recently-encountered visual world. However, even for neuronal properties as fundamental as orientation, much is unknown about adaptation-induced alterations in tuning. To delineate the influence of adaptation on neural and network properties, we investigated its effect in functionally distinct cell categories (excitatory vs inhibitory) in two hierarchically-related brain regions, V1 and V2, of the primate visual pathway. We performed multitetrode recordings from 90 neurons in V1 and V2 of 6 macaques using drifting sinusoidal gratings, after adaptation to a preferred and a non-preferred orientation for brief (0.4 s) and prolonged (40 s) exposures. We found a wide range of tuning changes induced by adaptation. In layer 2/3, orientation selectivity either increased or decreased, and the tuning curve peak moved either towards (attractive) or away from (repulsive) the adapter. In contrast, Layer 4 neurons typically broadened their tuning after brief adaptation and narrowed their tuning after prolonged adaptation. In V1, findings were similar for inhibitory and excitatory neurons (as distinguished by their extracellular action potential shape). However, in V2, prolonged adaptation broadened the tuning of inhibitory cells, but narrowed the tuning of excitatory cells. Thus, there is a wide variety of tuning changes induced by adaptation in both V1 and V2, and dynamics of adaptation are distinct in excitatory and inhibitory neurons within V2. Notably, these findings have implications for the circuit mechanisms of orientation selectivity: attractive shifts do not occur in purely feedforward models, or in recurrent models in which inhibitory neurons are untuned. In sum, tuned inhibitory neurons contribute not only to orientation tuning, but also to how this tuning adapts – and hence, play a critical role in the neural representations that ultimately influence perception

33.4101 **Auditory Crossmodal Plasticity Can Activate Visual Regions Automatically and Mildly Deactivate Natural Vision** Noelle Stiles[1](nstiles@caltech.edu), Vikram Chib[2], Shinsuke Shimojo[1]; [1]Biology and Biological Engineering, MC 139-74, California Institute of Technology, Pasadena, CA, 91125, USA, [2]Biomedical Engineering, Johns Hopkins University, Baltimore, MD, 21215, USA Kennedy Krieger Institute, Baltimore, MD, 21215, USA

Background Auditory sensory substitution (SS) devices, such as the vOICe, encode visual information into sound in real time, with the goal of aiding the blind. The vOICe translates an image's horizontal dimension into sound scan-time, vertical dimension into frequency, and pixel brightness into loudness. SS training and use engenders crossmodal plasticity in the blind and sighted so that the auditory input from the device generates early visual region activation during SS tasks. Nevertheless, unlike vision, vOICe interpretation is slow and laborious even after training, and therefore is often assumed to be processed top-down. Method We investigated whether sighted (N = 10) and blind (N = 4) participants can crossmodally activate the visual cortex with vOICe without attention following vOICe training. In a distract fMRI task, participants were distracted by counting backward during the playing of vOICe sounds encoded from white noise images. In a control fMRI task participants detected a flicker in the display of white noise images. Results Early visual regions (i.e. BA 18 and 19) and multisensory regions were activated during a vOICe distraction task in sighted and blind participants (post-vOICe-training – pre-vOICe-training). The automatic visual activation from vOICe (i.e. during a distraction task) is not likely due to visualization, because the neural activations were not correlated with participant post-hoc reports, nor with Vividness of Visual Imagery Questionaire scores. Furthermore, visual deactivation during a visual task was found in sighted participants ([pre-vOICe-training – post-vOICe-training], to highlight deactivation). Visual deactivation significantly correlated with sighted participants vOICe training performance. Discussion Our results indicate that SS can be processed in visual cortical regions without top-down attention in sighted and blind vOICe users. Visual deactivation following vOICe training may indicate that natural vision is weakened by crossmodal training via a competition for dominance between crossmodal and natural visual inputs to visual cortical regions

Perceptual Learning: Models, mechanisms, and clinical

Sunday, May 15, 8:30 am - 12:30 pm
Poster Session, Pavilion

33.4102 **Improving visual functions in amblyopia and mild myopia with perceptual learning and concurrent transcranial random noise stimulation** Rebecca Camilleri[1](beckycamilleri@gmail.com), Giuseppe Lo Giudice[2,3], Antonella Veronese[2], Andrea Pavan[4], Gianluca Campana[1,5]; [1]Department of General Psychology, University of Padova, Italy, [2]San Paolo Ophthalmic Centre, San Antonio Hospital, Padova, Italy, [3]Department of Ophtalmology, University of Padova, Italy, [4]School of Psychology, University of Lincoln, UK, [5]Human Inspired Technology Research Centre, University of Padova, Italy

Perceptual learning, an improvement in a sensory/perceptual task following practice and due to neural plasticity, has been shown to generalize and transfer to unrelated visual functions such as visual acuity (VA) or contrast sensitivity (CS) in participants with either cortical (e.g. amblyopia) or refractive deficits (e.g. myopia). It has recently been proposed that neural plasticity can be boosted with high-frequency transcranial random noise stimulation (hf-tRNS). Here we tested the efficacy of short trainings (8 sessions) of a contrast-detection task with concurrent hf-tRNS, in improving VA and CS of adults with amblyopia or uncorrected mild myopia. Results show that a short contrast-detection training can improve VA and CS in participants with amblyopia or uncorrected mild myopia only if coupled with hf-tRNS, whereas no effects were seen with the sole administration of the perceptual training or hf-tRNS.

33.4103 **Dyslexics show deficiencies in visual statistical learning: Evidence for a high-level visual processing deficit in dyslexia** Árni Kristjánsson[1](ak@hi.is), Hilda Danielsdottir[1], Margret Gudmundsdottir[1], Kristjan Hjartarson[1], Elin Thorarinsdottir[1], Heida Sigurdardottir[1]; [1]Department of Psychology, University of Iceland

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Dyslexia is generally considered to have linguistic roots and to involve impairments in phonological processing. But recent evidence from our laboratory indicates that people with dyslexia are impaired in their recognition of faces and other visually complex objects. This raises the question of whether the difficulty that people with dyslexia experience with reading might be the most salient manifestation of a more general high-level visual deficit. The visual word-form area (VWFA) in the left fusiform gyrus – which is involved in the processing of words but also faces and other objects – has consistently been shown to be hypoactive in dyslexics. Most importantly for the current goals, its responses appear to be shaped by visual statistical learning (VSL). If such learning is compromised, people should be less sensitive to statistically likely visual fragments – including word fragments – and impaired visual word and object recognition should be expected. No direct tests of whether dyslexia involves impairments in VSL have been performed, however. Forty diagnosed dyslexics and 40 matched typical readers participated in tests of temporal visual statistical learning of base pairs of novel shapes that frequently appeared together. Recognition of both individual shapes and base pairs (a measure of VSL) was tested. Dyslexics were impaired in VSL in comparison to typical readers, suggesting that VSL deficits contribute to dyslexia. Deficiencies in VSL may prevent experience-driven shaping of neuronal tuning in the VWFA, that otherwise occurs automatically. The VSL deficit was neither accounted for by differences in spatial attention paid to the stimuli nor by the ability to remember individual shapes.

Acknowledgement: University of Iceland Research Fund Icelandic Research Fund (IRF)

33.4104 **Improving collision detection in older adults using perceptual learning** Carissa Lemon[1](clemo001@ucr.edu), Denton DeLoss[1], George Andersen[1]; [1]Department of Psychology, University of California, Riverside

Numerous studies have indicated a decline in the ability of older adults to detect impending collisions. In addition, previous research has demonstrated that collision detection performance of college-aged subjects can be improved with perceptual learning. Thus the present study examined whether perceptual learning training can improve performance in collision detection in older subjects. Eight older subjects participated in the experiment, which was conducted over seven days with each day consisting of a 1-hr session. Collision detection thresholds for three observer speeds were measured prior to training using a two-alternative forced choice procedure during which participants indicated whether an approaching object would result in a collision or non-collision event. Participants were then trained near threshold at one of these speeds for 5 days. After training participants' thresholds were measured again. Results indicate a significant reduction in the time needed to detect a collision at the trained speed, $F(1,7)= 14.115$, $p=.007$. The interaction of day and speed was not significant, $F(2,14)=2.22$, $p>.05$. However, planned comparisons showed a reduction in the time needed to detect a collision at slower observer speed conditions, $t(7) = 2.798$, $p< .05$, and $t(7)= 4.279$, $p< .05$. Results in the higher observer speed condition were not significant, $t(7)=2.22$, $p=.559$. Results demonstrate that collision detection performance for older subjects can be improved with perceptual learning and may transfer to untrained observer speeds.

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33.4105 **Discrimination training enhances the fidelity of visual working memory** Ke Jia[1,2,3](jiake9728@163.com), Sheng Li[1,2,3]; [1]Department of Psychology and Beijing Key Laboratory of Behavior and Mental Health, [2]Key Laboratory of Machine Perception (Ministry of Education), [3]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, 100871, China

The delayed discrimination task has been extensively used in the studies of perceptual learning. Plastic changes at sensory cortex or decision-related brain areas are suggested to contribute to the observed training effect, whereas an important cognitive process involved in this task, working memory (WM), is mostly ignored. The underestimate of the WM process may stem from studies showing that the discrimination threshold was barely affected by the inter-stimulus interval (ISI), indicating that WM is perfect (Magnussen et al., 1990). However, recent studies measured the fidelity of WM directly and found that the precision of WM is lower than that of perception (Brady et al., 2013). This result raised the question of whether the delayed discrimination training enhances the fidelity of WM, perception, or both of them. To address this issue, we trained participants with an orientation discrimination task (peripheral, 6.5°, at the top left corner; ISI, 0.6 s; orientation, 45°). Before and after the training, we measured the fidelities of WM and perception. The fidelity was defined as the reciprocal of the standard deviation of the error distribution in a recall task. In this task, a Gabor patch and a red line, both in random orientations (drawn from uniform distribution over [40°-50°] independently), were presented either successively (for measuring WM precision, ISI = 0.6 s, 4 s or 8 s) or simultaneously (for measuring perceptual precision). Participants were instructed to adjust the orientation of the line until it matched the orientation of the Gabor patch. Our results showed significant training effect on WM precision, but not on perceptual precision. The changed fidelity of WM was highly correlated with the learning effect across participants and was specific to the trained location and ISI. These results suggest that the enhanced precision of WM may play an important role in perceptual learning.

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33.4106 **Eye movements determine which of multiple regularities are acquired during statistical learning** Yoko Higuchi[1](higuchi@cv.jinkan.kyoto-u.ac.jp), Nicholas Turk-Browne[2]; [1]Graduate School of Human and Environmental Studies, Kyoto University, [2]Department of Psychology, Princeton University

The visual environment is highly structured in terms of how objects appear with respect to each other in time and space. Studies of statistical learning have sought to investigate how such regularities are acquired, but they often employ simplified displays that lack the complexity of natural input. For example, in temporal statistical learning, a sequence containing regularities is typically presented one object at a time, whereas dynamic natural input contains multiple objects from moment-to-moment, where regularities could exist in all possible transitions. In such situations, what determines which regularities we learn? The present study tested the hypothesis that an initial, even idiosyncratic bias in eye fixation could tip the scales. During exposure, participants viewed sequences in which a scene (A) was followed by two objects (B and C). From this, they could learn to expect B and/or C after A. We predicted that whichever object they first fixated in the double array would be more strongly bound to A. At test in Experiment 1, participants viewed sequences in which an exposure scene (A) was followed by one object (B or C), and they had to categorize the object as quickly as possible. Faster RT was taken as evidence that the scene-object pair had been learned and that the scene set up an expectation of the object. Consistent with the hypothesis, whichever object tended to be fixated first during exposure was categorized more quickly. To examine learning another way, Experiment 2 used a familiarity test in which participants discriminated two sequences: a scene-object pair from exposure (e.g., A-B) and a "foil" sequence (e.g., A-D). Discrimination was only reliable for pairs containing the initially fixated object. These findings provide evidence that attention and eye movements constrain which of all possible regularities in the world we learn.

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33.4107 **Feature conjunction learning is an enduring form of visual learning** Sebastian Frank[1](sebastian.m.frank.gr@dartmouth.edu), Mark Greenlee[2], Peter Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]Institute for Experimental Psychology, University of Regensburg

We report evidence that feature conjunction learning represents an enduring form of visual learning. Participants were trained on a visual search task for feature conjunctions consisting of moving trajectories (Frank et al. 2015 Cerebral Cortex). The first and last training sessions were carried out during functional magnetic resonance imaging. After three weeks of training, participants improved remarkably in performance, indicative of learning. This improvement was differentially pronounced across trained retinotopic locations, revealing a unique perceptual learning pattern for each participant. As a result of training, activity in motion-sensitive area MT+ (V5) increased. Having demonstrated learning, we were interested in the long-term stability of these learning effects. Therefore, participants were retested in the learning task three months, one year, and two years after the end of training. Acquired behavioral improvements were remarkably stable over time and still present even two years after the end of original training. This was also true for each participant's retinotopic learning pattern, such that better performance during retests was achieved at retinotopic locations where participants had learned best. Activity changes during training also predicted later retest performance: the higher the change of activity in area MT+ during training, the better participants performed two years later. Our results show that feature-conjunction learning, once established, remains stable over years and represents an enduring form of visual learning.

33.4108 **Attention is necessary for the learning of visual feature conjunctions, but a small amount is as good as a lot** Liwei Sun[1](liwei.sun.gr@dartmouth.edu), Sebastian Frank[1], Peter Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Our previous work (Frank et al., 2014, Human Brain Mapping) showed that search for visual feature conjunctions (e.g., conjunctions of color and location) becomes efficient after a few days of training. However, it is unclear what role attention plays in the learning of complex feature conjunctions. Does learning occur only if participants pay attention to the to-be-learned target/distractor stimuli? And if so, does the amount of learning correlate with the amount of attention deployed? To answer these questions, we used an attentionally demanding RSVP task at the screen center with pre-adjusted levels of difficulties, while search stimuli (red-green bisected disks or T/L) were passively presented in the periphery. In Experiment 1 participants performed eight days of training on the RSVP task and two dual-task sessions (RSVP and active search on the conjunction stimuli) before and after training. Results showed no significant improvement on the search task, suggesting that attention is necessary for learning of feature conjunctions. In Experiment 2, participants were trained on the same dual-task paradigm as in the test sessions of Experiment 1 for ten days. Two pairs of search stimuli were used (red-green bisected disks and T/L). Each target/distractor pair was presented during either a low- or high- attentional load central RSVP task. Results indicate that participants learned both pairs of conjunction stimuli and the magnitude of learning did not differ between low-load and high-load central task conditions. This suggests that learning effects do not increase with more attention deployed to the conjunction stimuli, and that a low level of attentional allocation is sufficient for learning to take place. In sum, our results suggest that attention is necessary for the learning of visual feature conjunctions, while the amount of attention allocated beyond some minimal level does not impact the efficiency of learning.

33.4109 **Perceptual Learning of Motion Direction Discrimination Induced by True and False Feedback** Qi Zhang[1,2,3](1163898863@qq.com), Sheng Li[1,2,3]; [1]Department of Psychology and Beijing Key Laboratory of Behavior and Mental Health, [2]Key Laboratory of Machine Perception (Ministry of Education), [3]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, 100871, China

Top-down factors such as feedback plays an important role in learning. However, in the literature of perceptual learning, only a few studies have focused on this topic. In the present study, we investigated how different types of feedback affect perceptual learning of motion direction discrimination. We trained participants for six days to discriminate whether the direction of moving dots was the same as the orientation of a fixed reference bar that preceded. The direction was either the same or deflected 1° to one side of the reference orientation during training. The participants were assigned to three groups based on the types of feedback they received during training: true feedback, false feedback, and random feedback. For the true feedback and false feedback groups, we analyzed the data from the learners who correctly reported the deflection and improved discrimination sensitivity, in accordance with their received feedback, after the training. A three-way repeated measure ANOVA for learners in both true and false feedback conditions revealed significant triple interactions among training, direction, and deflection (trueFB:$F(1,11)= 13.512$, $p=0.004$; falseFB: $F(1,11)= 17.179$, $p=0.002$). Additional analysis revealed that d' significantly changed only for trained direction and deflection after training, but not for other directions or deflections. These findings suggest that feedback can exert significant effect on the learning of motion direction discrimination. Particularly, the false feedback to the subthreshold stimuli during training led to wrong perception and such effect was limited to the trained condition.

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33.4110 **Properties of exposure-based motion direction learning** Gong-Liang Zhang[1](zh_g_l@163.com), Cong Yu[2]; [1]Department of Psychology, Soochow University, Soochow, China, [2]Department of Psychology and Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China

Although most perceptual learning studies focus on task-relevant learning, task-irrelevant exposure-based learning (EBL) also occurs as a result of observers' mere exposure to a stimulus feature (Watanabe et al. 2001, Gutnisky et al. 2009). Here we investigated properties of EBL of motion direction discrimination. Observers were passively exposed to random dot kinematogram (RDK) for 5 daily sessions. Before and after exposure, a staircase procedure was used to estimate motion direction discrimination thresholds. We found that (1) After the observers were exposed to subthreshold RDK(coherence = 10%) or null-coherence RDK (coherence = 0) while only performing an irrelevant luminance discrimination task in catch trials (20%), motion direction thresholds were improved significantly at the exposed direction by 41.9 ± 7.0% ($p< 0.001$) and an unexposed orthogonal direction by 35.3 ± 8.1% ($p< 0.001$), or at any direction by 35.8 ± 3.2% ($p< 0.001$) when coherence = 0. (2) The EBL required a pretest of the motion direction discrimination task. Otherwise the improvement was substantially reduced and insignificant (10.0 ± 7.4%, $p= 0.21$). (3) When the subthreshold RDK (coherence = 10%) was paired with an irrelevant luminance discrimination task every trial with feedback, significant reduction of direction discrimination thresholds was evident only at the exposed direction (31.0 ± 4.1%, $p < 0.001$), but not at an orthogonal direction (7.3 ± 3.7%, $p = 0.10$). (4) When attention was distracted from RDK (coherence = 0%) by a central RSVP task, no significant threshold changes were observed (8.7 ± 6.3%, $p= 0.24$). These results indicate that the interaction between pretest task priming and stimulus exposure, as well as attention to exposed stimulus, are essential for EBL to occur. Reinforcement signals are not required for EBL, but they may gate EBL by limiting EBL to directions that are temporally associated with the reinforcements.

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33.4111 **Sequential Effect on Visual Classification: The Citrus Classification Paradigm** Taeyang Yang[1](tyyang@unist.ac.kr), Oh-Sang Kwon[1]; [1]Department of Human Factors Engineering, Ulsan National Institute of Science and Technology

Introduction: Prior knowledge affects performances in diverse perceptual and cognitive tasks (Caillies, S. et al., 2002; Johnson, E. J., & Russo, J. E., 1984), and human can adaptively learn mean and variance of the prior distribution (Berniker M., et al., 2010). In existing studies, however, samples from prior distribution were presented in random order, thus the effect of sequential order on the construction of prior distribution has not been explicitly tested. Here, we examined how the order of stimuli presentation affects the learning of prior distribution. Methods: Experiment consists of training and test sessions. In training session, which was to expose subjects to the prior distribution of stimuli size in a particular sequence implicitly, subjects were asked to classify fresh and rotten citrus according to the color. There were three conditions. In increasing or decreasing size conditions, the size of stimuli increased or decreased gradually with additional random fluctuation. In random size condition, the size of stimuli randomly varied. Each subject ran 630 trials in one of three conditions. Distribution of stimuli diameters was uniform between 1.4° and 4.3° in visual angle for all conditions. In test session, subjects classified 420 citruses of various sizes, which follow identical distribution used in training, into three size categories (small/medium/large) based on their own criteria. In both sessions, stimuli were presented at random position in the screen to prevent making virtual criteria for classification. Results: Subjects' internal criteria for classification in test session were modulated by the order of stimuli presentation in training sessions. The proportion of 'medium' responses was the lowest in increasing size condition and the highest in decreasing size condition, presumably reflecting the difference in estimated variance of stimuli distribution. Conclusion: We showed that the order of stimuli affect the learning of prior distribution and estimating criteria for classification using a novel experimental paradigm.

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33.4112 **Dynamic estimation of prior probabilities in an orientation-discrimination task** Elyse Norton[1](ehn222@nyu.edu), Michael Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Optimal sensory decision-making requires the combination of uncertain sensory signals with prior expectations. Signal detection theory describes the effect of prior probabilities as a shift in the decision criterion (i.e., response bias). Previous studies typically vary category probability between blocks and assume a fixed criterion for each block. Can observers track sudden changes in probability? We determine how observers update the decision criterion as category probabilities change. Stimuli were ellipses with orientations drawn either from category A or B. For each category, ellipse orientation was drawn from a Gaussian distribution. The category distributions were partially overlapping with different means and equal variance. Observers performed two tasks in separate sessions. (1) Covert-criterion task: An ellipse was shown and the observer indicated the category by keypress. (2) Overt-criterion task: The observer adjusted the orientation of a "criterion line" and then an ellipse was presented and cat-

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egorized based on the criterion line's orientation. Feedback was provided in both tasks. Before each session, observers were trained on the category orientation distributions (2AFC, equal category probabilities). For both tasks, category probabilities were updated using a sample-and-hold procedure. The probability for category A (p) was randomly selected from a set of five probabilities (range: [.20, .80]). The probability for category B was 1-p. Probabilities were updated every 80-120 trials. In both tasks, observers tracked changes in category probabilities and used these estimates to modify the decision criterion. We compared observer performance to the optimal "omniscient" observer (i.e., an observer that sets the decision criterion optimally and knows the exact category probability on every trial) and found that observers undercompensated for changing probability. We will compare several additional models of task performance ranging from a simple reinforcement-learning model to models that explicitly estimate category probability and use that information to set the decision criterion.

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33.4113 **Modulating acetylcholine during consolidation of sleep-dependent perceptual learning** Elizabeth McDevitt[1](mcdevitt@ucr.edu), Maryam Ahmadi[1], Michael Silver[2], Sara Mednick[1]; [1]Department of Psychology, University of California, Riverside, [2]School of Optometry and Helen Wills Neuroscience Institute, University of California, Berkeley

Rapid eye movement (REM) sleep plays a critical role in consolidation of perceptual learning (PL), and high levels of acetylcholine (ACh) during REM are hypothesized to set the appropriate neural dynamics for this process (Mednick et al., 2003). Prior work has demonstrated that cholinergic enhancement increases the magnitude and specificity of PL (Rokem & Silver 2010, Beer et al., 2013), however these studies either were unable to dissociate ACh enhancement effects on training versus consolidation or did not measure sleep. Using a between-subjects design, we compared the cholinesterase inhibitor rivastigmine (n=6), which increases synaptic levels of ACh, to placebo (n=7) during the first of two nights of sleep following training on a texture discrimination task. Preliminary results show no difference in initial encoding thresholds between drug groups (p=.55). Difference scores between encoding and retrieval reveal significant learning in the rivastigmine condition (p=.012), but no learning in the placebo condition (p=.27). Currently, there is no significant difference in magnitude of learning between drug groups (p=.14), however, more data need to be collected. In summary, this study uses an innovative approach to examine neural mechanisms of sleep-dependent memory consolidation with pharmacology in humans. Our early results show a possible role for acetylcholine in the enhancement of perceptual memories.

Acknowledgement: NSF 1439210

33.4114 **Biases in human sequential predictions as a consequence of incorrect world models, noise and limited memory** Devika Narain[1,2](dnarain@mit.edu), Robert van Beers[2], Jeroen Smeets[2]; [1]McGovern Institute for Brain Research, Massachusetts Institute of Technology, Cambridge, MA, USA, [2]MOVE Research Institute Amsterdam, VU University, Amsterdam, The Netherlands

Recent studies demonstrate that biases found in human behavior can be explained by rational agents that make incorrect generative-model assumptions. While predicting a sequence of uncorrelated events, humans are biased towards overestimating its serial correlation. We demonstrate how such biases may also be the consequence of considering noisy observations over limited timescales of previous observations. We use the Kalman filter (KF) to study the upper-bound on human prediction performance. We investigate how the brain could estimate the necessary parameters for the KF based on the only source of information available to it, previous observations. We develop a variant of the KF model (dual memory) that obtains estimates of the KF parameters and its state over limited timescales of previous observations. The dual memory model predicts that the serial correlation should be veridical in responses for observations that are correlated in time and should be overestimated for uncorrelated ones. Second, the extent of overestimated correlation in the responses should be robust to varying noise-levels. Third, the overestimated correlation should persist regardless of whether previous observations are shown or not, if the same world-model is used. To test these hypotheses we performed an experiment where human observers were asked to predict time series, each with varying autocorrelations and noise-levels. One group was provided brief feedback whereas another was provided the history of observations. We found that the behavior of the participants was consistent with all three predictions. Further, we found a strong agreement between predictions of the dual memory model and previous empirical reports of bias in human forecasts of time series. We conclude that a markovian state-estimation model that would otherwise be optimal in predicting time series, displays the same biases in its predictions as humans do if it obtains parametric information over limited timescales of noisy observations.

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33.4115 **Perceptual learning with minimal V1 plasticity** Xinyu Xie[1](xiexy518@pku.edu.cn), Cong Yu[1,2]; [1]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China, [2]Department of Psychology, Peking University, Beijing, China

Visual perceptual learning (VPL) studies typically train a specific stimulus feature at a specific retinal location, and learning is often attributed to training-induced V1 plasticity because of the location and feature specificity. However, recent double training studies from our lab challenged the specificity observations and the V1-plasticity explanation. Here we present a new study that minimizes V1 plasticity by design in a orientation discrimination task. Two groups of observers practiced a peripheral orientation discrimination task with Gabor stimuli at 5° retinal eccentricity. Both groups had pre- and post-training thresholds measured at the same test location and orientation. The control group practiced the test condition for five sessions. The experimental group followed the same procedure, but the Gabor location rotated along the 5°-eccentricity circle every trial at 12 preset locations (30° apart between neighboring locations). The Gabor orientation also rotated at 4 preset orientations (45° apart), but it would jump to the next orientation if the Gabor was shown at the test location and its orientation was rotated to the test orientation. For each combined orientation-location condition, only 60 trials were practiced, which was 1/48 of the trials the control group practiced at the test condition. Neurons respectively responding to each stimulus condition in the retinotopic and orientation selective V1 were thus minimally trained and those responding to the test condition were not trained. Training reduced orientation thresholds at the test condition by 32.0 ± 9.4% (p = 0.015, two-tailed paired t-test) in the experimental group and by 31.0 ± 10.5% (p = 0.041) in the control group. There was no significant difference of learning between the two groups (p = 0.944). These results indicate that orientation learning can be achieved with minimal V1 plasticity, which is consistent with our claim that VPL is a high-level cognitive process.

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33.4116 **Perceptual learning of contrast detection strengthens the response of the magnocellular layers of the human LGN** Qinlin Yu[1](yu.psy@qq.com), Peng Zhang[4], Fang Fang[1,2,3]; [1]Peking-Tsinghua Center for Life Sciences, [2]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), [3]IDG/McGovern Institute for Brain Research Peking University, Beijing 100871, China, [4]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing 100101, China

In this study, we carried out psychophysical and fMRI experiments to investigate whether perceptual learning of contrast detection can modify the response properties of the lateral geniculate nucleus (LGN). Nineteen subjects underwent thirty daily training sessions to detect the presence of a checkerboard with one eye. The checkerboard was presented briefly at a near-threshold contrast in one visual hemifield. A daily session consisted of 30 QUEST staircases of 40 trials. Before and after training, we measured subjects' contrast detection thresholds and contrast response functions of BOLD signal. Their behavioral improvement was specific to the trained eye and the trained hemifield. During scanning, flickering checkerboards at three contrast levels (6%, 24%, or 96%) were presented in either the left or the right visual hemifield. Subjects viewed the stimuli with one eye. Meanwhile, they needed to detect the color change of the central fixation point. Training led to an eye- and hemifiled-specific response increase of the LGN to the checkerboard, only at the low contrast level (6%). There was no learning-induced change in V1, V2, and V3. Furthermore, we used the method proposed by Zhang et al. (2015) to separate the Parvocellular (P) and Magnocellular (M) layers of the LGN. We found that, following training, only the response of the M layers increased to the low contrast checkerboard. The response increase in the M layers significantly correlated with the behavioral improvement. Our study demonstrated that even in the absence of top-down modulation (e.g. attention), perceptual learning of contrast detection could modify the functional properties of the M layers of LGN by increasing their response gain to low-contrast stimuli.

Perceptual Learning: Adaptation and specificity

Sunday, May 15, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Steve Engel

34.11, *2:30 pm* **Long-term adaptation to ocular aberrations alters visual processing of spatial frequency information**

Antoine Barbot[1,2](antoine.barbot@nyu.edu), Krystel Huxlin[1,2,3], Duje Tadin[1,2,3], Geunyoung Yoon[1,2]; [1]Flaum Eye Institute, University of Rochester Medical Center, NY USA, [2]Center for Visual Science, University of Rochester, NY USA, [3]Department of Brain and Cognitive Sciences, University of Rochester, NY USA

Background: Optical aberrations alter visual processing, limiting the benefits of advanced correction methods. Here, we investigated the mechanisms by which prolonged, chronic exposure to optically degraded visual inputs alters processing in normally developed adults with keratoconus (KC)–a severe and progressive corneal disease. Procedure: We used an Adaptive Optics Vision Simulator (AOVS) to fully correct and/or induce optical aberrations in both KC observers (n=7) and age-matched controls (n=7) while measuring visual performance at fixation. Specifically, we measured: visual acuity (VA) thresholds for broadband Snellen E-letter stimuli, contrast sensitivity (CS) for Gabor narrowband stimuli and CS for broadband natural images. Then, we used an external noise paradigm to characterize properties of channels selective to low (1-cpd), intermediate (3-cpd) and high (9-cpd) spatial frequencies (SF). We assessed whether sensitivity differences were due to changes in external noise filtering and/or internal noise using the Perceptual Template Model. Results: Under identical, aberration-free conditions, KC observers showed lower VA and poorer CS for high SFs relative to normal participants, consistent with previous studies. KC's impaired sensitivity at high-SFs despite full optical correction reflected both poorer external noise filtering and higher internal noise, consistent with channel reweighting. Then, we induced KC's habitual optical aberrations into normal participants using the AOVS. Under their own habitual aberration conditions, KC observers showed better VA and CS for broadband information than normal participants, but similar performance was observed using narrowband stimuli. Conclusion: Our findings provide fundamental insights into the mechanisms of long-term adaptation to optical aberrations. KC observers showed an advantage for broadband information processed through their own habitual aberrations, suggestive of a compensatory mechanism that partially restores phase congruency across SFs. Furthermore, KC observers experienced limited benefits from full optical correction, and we showed that this was likely due to reduced sensitivity to high-SFs caused by channel reweighting.

Acknowledgement: NIH/NEI RO1 EY014999 to GY, KH and DT

34.12, *2:45 pm* **Habitual wearers of colored lenses adapt more rapidly to the color changes they produce**

Stephen Engel[1](engel@umn.edu), Arnold Wilkins[2], Shivraj Mand[3,4], Peter Allen[3,4]; [1]Department of Psychology, University of Minnesota, [2]Department of Psychology, University of Essex, [3]Department of Vision and Hearing Sciences, Anglia Ruskin University, [4]Vision and Eye Research Unit, Anglia Ruskin University

Can the visual system learn to adapt particularly rapidly to large, commonly occurring changes in input? Every time one takes off or puts on a pair of glasses, the statistics of visual input change dramatically. It would be advantageous if vision could adapt especially efficiently to such changes, but whether it does so remains unknown. We tested whether people who routinely wear spectacles with colored lenses (prescribed for "visual stress") increase how rapidly they adapt to the color shifts their lenses produce. Nine habitual wearers and nine age-matched control subjects judged the color of a small monochromatic test light presented on a large, uniform, whitish surround, every 5 sec for repeated 1 min periods. The "method of a thousand staircases" was used to estimate the timecourse of changes in unique yellow, the wavelength appearing neither reddish or greenish, over 1 min periods following the donning and removal of their spectacles. As expected, red lenses shifted unique yellow to more reddish colors (longer wavelengths), and greenish lenses shifted it to more greenish colors (shorter wavelengths), consistent with adaptation "normalizing" the appearance of the world. We quantified rapid adaptation as shifts in unique yellow occurring by the first time point (5 sec) and slow adaptation as shifts occurring thereafter. Critically, in habitual wearers rapid adaptation to their habitually worn color was reliably larger (~7 nm vs ~4 nm), and slow adaptation reliably smaller (~0 nm vs 0.75 nm) than in controls. The total amount of adaptation was also larger in habitual wearers. These data strongly suggest that the visual system adapts more rapidly and strongly as environments are encountered repeatedly. Our results represent one of the first formal tests of the anecdotal observation that adjusting to putting on one's glasses becomes easier over time, and may have implications for clinical management.

Acknowledgement: NSF BCS1028584

34.13, *3:00 pm* **Spontaneous recovery of effects of contrast adaptation without awareness**

Gaoxing Mei[1,2](meigx@psych.ac.cn), Xue Dong[1], Bo Dong[1], Min Bao[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, P.R. China, [2]Department of Psychology, Guizhou Normal University, Guiyang, P.R. China

Prolonged exposure to a high contrast stimulus reduces the neural sensitivity to subsequent similar patterns. Recent work has disclosed that contrast adaptation is controlled by multiple mechanisms operating over differing timescales (Bao and Engel, 2012; Bao, Fast, Mesik, & Engel, 2013). Adaptation to high contrast for a relatively longer period can be rapidly eliminated by adaptation to a lower contrast (or meanfield in the present study). Such rapid deadaptation presumably causes a short-term mechanism to signal for a sensitivity increase, canceling ongoing signals from long-term mechanisms. Once deadaptation ends, the short-term mechanism rapidly returns to baseline, and the slowly decaying effects in the long-term mechanisms reemerge, allowing the perceptual aftereffects to recover during continued testing. Although this spontaneous recovery effect is considered strong evidence supporting the multiple mechanisms theory, it remains controversial whether the effect is mainly driven by visual memory established during the initial longer-term adaptation period. In Experiment 1, adapting stimuli were either visible or rendered invisible with a modified Continuous Flash Suppression (CFS) paradigm. We used a contrast matching task to track the dynamic of effects of adaptation. We found reliable spontaneous recovery emerging rapidly in the initial phase of the post-test for both visible and invisible adapters. In Experiment 2, the adapting grating was either displayed alone or flanked by other similar gratings (i.e. a 'crowding' paradigm introduced by He, Cavanagh, & Intriligator, 1996). The time course of contrast detection thresholds were tracked on the same purpose. Spontaneous recovery was found not only in the adapter-alone condition but also in the crowded condition (orientation indiscernible). These results exclude the possibility that spontaneous recovery found in the previous work is merely the consequence of explicit visual memory. Our findings also demonstrate that contrast adaptation, even at the unconscious processing levels, is controlled by multiple mechanisms.

34.14, *3:15 pm* **Creation of no-aftereffect-based associative learning of color and orientation without presenting color by decoded fMRI neurofeedback.**

Kaoru Amano[1,2](kaoruamano@nict.go.jp), Kazuhisa Shibata[3], Mitsuo Kawato[4], Yuka Sasaki[3], Takoe Watanabe[3]; [1]Center for Information and Neural Networks (CiNet), National Institute of Information and Communications Technology, [2]Precursor Research for Embryonic Science and Technology, Japan Science and Technology Agency, [3]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [4]Brain Information Communication Research Laboratory Group, Advanced Telecommunications Research Institute International

Introduction: Associative learning is an essential brain process in which different items are learned to be associated. Although some studies have found that learning of a single feature (perceptual learning) involves the early visual cortex (e.g. Shibata et al, 2011, Science), there is no clear evidence that associative learning of different visual features occurs in the region. Here, via a new fMRI decoded neurofeedback method, we tested whether associative learning of color and orientation can be created in the early visual cortex. Methods: First, based on fMRI signals in V1/V2 that responded to each of red and green grating, a classifier was constructed to optimally classify these signals into red or green. During the following training, a physically presented achromatic vertical grating was associated with V1/V2 activation patterns corresponding to red.

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While the achromatic grating was presented, participants were instructed to regulate brain activity to make a to-be-displayed disk as large as possible. FMRI signals in V1/V2 were inputted to the classifier, which determined the "red" likelihood. Unbeknownst to participants, the determined likelihood was then reflected in the updated disk size. After the training, chromatic psychometric functions were measured for both the trained and untrained orientations. Results: Participants learned to induce activation patterns in V1/V2 that are similar to the patterns evoked by red gratings while a vertical achromatic grating was presented. Importantly, inductions of these activation patterns paired with the vertical achromatic grating led participants to more likely perceive the trained vertical grating as red than green. This associative learning persisted at least 3 to 5 months. In contrast to the McCollough effect that shows complicated association of orientation and the color complementary to an adapted color, the present results provide the first direct evidence that the early visual cortex has the capability in forming long-lasting associative learning.

Acknowledgement: NIH R01 EY019466-07, NSF BCS 1539717

34.15, *3:30 pm* **Perceptual learning and the spatial frequency tuning of the perceptual template** Barbara Dosher[1](bdosher@uci.edu), Zhong-Lin Lu[2], Nathaniel Blair[3]; [1]Cogntive Sciences Department, University of California, Irvine, [2]Department of Psychology, The Ohio State University, [3]California State University, Sacramento

We investigated the mechanisms by which perceptual learning improves performance with practice using high- and low-pass filtered external noise. Observers were trained in a 4AFC orientation identification task with Gabor stimuli embedded in external noise at two spatial locations. The spatial frequency characteristics of external noise were systematically manipulated through high-pass and low-pass filtering and added to the signal stimulus. Contrast thresholds were measured as a function of the cutoff spatial frequency of the high-pass and low-pass filters and practice. Adaptive staircases adjusted contrasts to track 79.4 and 70.7 percent correct with 1620 trials per session for a total of 18 sessions. Observers identified the orientation of the Gabor in the pre-cued location in each trial. Different spatial frequency conditions and locations were intermixed randomly during training. This is the first study to use filtered external noises during training. Observers showed systematic reductions in contrast thresholds over the course of training. Although the amplitude of the threshold versus cutoff frequency functions decreased, the relationship between the low-pass and high-pass threshold versus cutoff spatial frequency functions remained substantially equivalent through the course of perceptual learning. The performance returned essentially to initial levels after a switch to new retinal locations of testing, indicating specificity of the learning. A perceptual template model elaborated to estimate spatial frequency sensitivity of the template (Lu & Dosher, 2001) was used to account for the threshold versus cutoff functions through the course of training. We found that perceptual learning improved performance in external noise without changing the spatial frequency tuning of external noise sensitivity, in parallel with previous findings in spatially cued attention (Lu & Dosher, 2004). The improved tuning of the perceptual template with practice may occur in orientation rather than spatial frequency tuning.

Acknowledgement: NEI Grant # EY–17491 and NIMH

34.16, *3:45 pm* **Implicit updating of object representation via temporal regularities** Ru Qi Yu[1](ruqiyu@psych.ubc.ca), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

An adaptive function of the visual system is that it can flexibly update existing representations of objects upon changes in the environment. Moreover, these changes can alter the representations of other associated objects that are not directly visible. For example, the increasing size of headlights at night signals an approaching car, although the car may not be visible. What mechanism supports such inference? We propose that statistical learning provides a channel through which new information about one object can be transferred to related objects. Observers viewed a continuous sequence of circles grouped into color pairs (e.g., red always appeared before blue). Afterwards, the first circle in each pair increased or decreased in size. Observers recalled either the size of the second circle in the pair, or the size of a random circle that never followed the first one. We found that the size of the second circle was judged to be larger (or smaller) than the random circle if the first circle increased (or decreased) in size (Experiment 1). This suggests that changes in one object are automatically transferred to the object that previously reliably followed. This transfer may be facilitated by the fact that the first circle predicted the second circle, or the mere association between the two circles. To tease these ideas apart, in Experiment 2 the second circle increased or decreased in size, and observers recalled the size of the first circle, or a random circle. We found no difference between the judged size of the first circle and the random circle, suggesting that changes in one object are transferred to the predicted object, but not vice versa. No observer was explicitly aware of the color pairs. Thus, statistical learning implicitly and automatically updates the representation of objects upon changes to other objects via temporal prediction.

Acknowledgement: NSERC Discovery Grant

34.17, *4:00 pm* **Brief episodes of memory reactivation enable perceptual learning** Nitzan Censor[1](censornitzan@post.tau.ac.il), Shlomi Nemni[1], Rotem Amar[1]; [1]School of Psychological Sciences and Sagol School of Neuroscience, Tel Aviv University

Following initial encoding and consolidation of a perceptual memory, perception thresholds continue to gradually improve over multiple training sessions, similar to other forms of procedural learning (Censor, Sagi and Cohen, 2012). Here we show, that following initial training, brief periods in which the encoded visual memory is reactivated are sufficient to enable perceptual learning, comparable to learning achieved with repeated standard practice sessions. Participants trained with the texture discrimination task (Karni and Sagi, 1991). The texture stimulus was presented for 10ms, followed by a 100ms patterned mask. Observers decided whether an array of 3 diagonal bars embedded in an array of horizontal bars (19×19) was horizontal or vertical. The target-to-mask asynchrony (SOA) was randomly varied within the session (14 SOAs of 40-340ms, 18 trials per SOA) to obtain a psychometric curve, from which the SOA discrimination threshold was derived. The memory was first encoded and consolidated following a full session on Day1. Participants returned for three daily reactivation sessions (Days 2-4) of only 5 trials each, at a near-threshold SOA. On Day5, participants performed a full test session (identical to Day1). Learning, measured as improvement in discrimination thresholds from Day1 to Day5, was significant (31.7±12.0ms, mean±SE, $P < 0.02$) and comparable ($P=0.45$) to total learning in a control group of subjects performing five regular full daily sessions (39.4±11.4ms, $P < 0.005$). Learning in the reactivation group was long-term and retained for months, with retention even more pronounced than in the full practice group. Thus, brief reactivations of consolidated perceptual memories enable perceptual learning, possibly via reactivation-reconsolidation cycles of memory strengthening (Lee, 2008; Dudai, 2012; Nader and Hardt, 2009). This interpretation may have an important role in understanding the mechanisms underlying perceptual learning, and facilitate novel strategies geared to substantially reduce the amount of practice needed for learning in normal and neurological conditions.

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Spatial Vision: Neural mechanisms and models

Sunday, May 15, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Martina Poletti

34.21, *2:30 pm* **Toad lights up the prince of brightness illusions.** David Crewther[1](dcrewther@swin.edu.au), Nina Riddell[2], Laila Hugrass[1], Jude Jayasuriya[1], Sheila Crewther[2]; [1]Centre for Human Psychopharmacology, Swinburne University of Technology, [2]School of Psychology and Public Health, La Trobe University

Human psychophysics indicates that drifting gratings or diamonds shaded in a sawtooth pattern appear brighter when the direction of movement produces fast-OFF relative to fast-ON luminance profiles. Although a retinal basis has been speculated, the cellular mechanisms remain unclear. We recorded electroretinograms (ERGs) from toad eyecups presented with sequential epochs of sawtooth (fast-ON_slow-OFF and fast-OFF_slow-ON), sine-wave, and square-wave gratings drifting horizontally across the retina with drift temporal frequencies of 2.5 - 20Hz. ERGs revealed a sustained DC increase in trans-tissue potential during drift, plus a peak at drift offset. For sawtooth gratings, the DC potential effect was greater for fast-OFF cf fast-ON sawtooths, consistent with the perceptual strength of the brightness illusion in human. All gratings produced an increase in DC potential as temporal frequency increased. Modelling of the frame-based stimulus presentation showed changes in root mean square (RMS) temporal luminance contrast as a function of temporal frequency, in way that dif-

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fers between square, sine and sawtooth profiles. However, these effects could not explain the divergence in ERG response amplitudes for the two sawtooth profiles which remained immune to this frame-based phenomenology. Pharmacological probing indicated that the response amplitude difference for the two sawtooth profiles remained following suppression of post-receptoral activity with Tetrodotoxin (TTX) blocking ganglion cells and spiking amacrines, 2-Amino-4-Phosphonobutyric acid (APB) blocking ON bipolars, and cis-Piperidine-2,3-dicarboxylic Acid (PDA) blocking OFF bipolar cells. Thus, pharmacological dissection indicated that this DC difference originates from asymmetries in the photoreceptoral response to fast-ON and fast-OFF sawtooth profiles, suggesting the outer retina as the neural site of origin for the drifting sawtooth brightness illusion.

Acknowledgement: ARC DP110103784

34.22, *2:45 pm* **Predictive position percepts mediated by parietal areas: TMS evidence** Grace Edwards[1,2](edwards@cerco.ups-tlse.fr), Philippe Marque[3], Rufin VanRullen[1], Patrick Cavanagh[2,4]; [1]Centre de Recherche Cerveau & Cognition, Toulouse, France, [2]Laboratoire Psychologie de la Perception, Paris, France, [3]Médecine physique et de réadaptation, Toulouse, France, [4]Psychological and Brain Sciences, Dartmouth College, Hanover, NH

When the eyes move or a target moves, the target may be perceived at its predicted next location, displaced from its current retinal location. We hypothesised that this predictive mechanism is controlled by saccade maps found, for example, within the frontal eye fields (FEF) and the intraparietal sulcus (IPS). We examined whether repetitive transcranial magnetic stimulation (rTMS) over right FEF, right IPS, and a control site, peripheral V1/V2, diminished participants' perception of two cases of predictive position perception: trans-saccadic fusion, and the flash grab illusion. In trans-saccadic fusion, participants saccade toward a stimulus that is replaced with another stimulus at the same spatial location when the saccade lands, this frequently leads to a fused percept of both stimuli as if they had been presented together at the same location (Paeye, Collins, & Cavanagh, VSS2016). There was a main effect of rTMS condition on the frequency of trans-saccadic fusion ($F(3,11)4.25$, $p=0.012$) within 10 minutes of rTMS stimulation. rTMS to IPS led to a decrease in the frequency of trans-saccadic fusion reports in comparison to the no-TMS conditions ($t(11)=3.8480$, $p=0.0027$) and to rTMS to the control site ($t(11)=3.3192$, $p=0.0068$). rTMS to FEF also reduced the frequency of trans-saccadic fusion reports although not significantly (compared to no-TMS $p=0.059$, compared to control rTMS $p=0.091$). rTMS to the control site did not affect trans-saccadic fusion ($p=0.6592$). In the flash-grab illusion, a bar is flashed on a moving background leading to the percept that the bar has shifted in the direction of the motion after the flash (Cavanagh & Anstis, 2013). In contrast to the trans-saccadic fusion results, the reduction in the flash grab illusion after rTMS to IPS and FEF did not reach significance ($p=0.6004$.) These findings suggest that right IPS contains saccade maps that contribute to predictive position perception during trans-saccadic fusion.

Acknowledgement: ERC Position (PC)

34.23, *3:00 pm* **Functional implications of orientation maps in visual cortex** Erin Koch[1](ekoch@sunyopt.edu), Jianzhong Jin[1], Jose-Manuel Alonso[1], Qasim Zaidi[1]; [1]Graduate Center for Vision Research, State University of New York

Stimulus orientation is mapped in the primary visual cortex of primates and carnivores in a pinwheel pattern, with iso-orientation domains rotating around pinwheel centers. The circuit functions and perceptual implications of this orientation map remain unclear, as it is absent in many mammals such as rodents. We used simultaneous recordings from horizontally arranged neurons in cat visual cortex using linear arrays (32 electrodes, 100 microns apart), to distinguish horizontal tracks running through iso-orientation domains showing limited changes in orientation preference and narrow orientation tuning, from those running near pinwheel centers showing rapid changes in orientation preference and broad tuning. The results showed that two fundamental properties of visual cortical responses, contrast saturation and cross-orientation suppression, are closely related to the functional organization of orientation maps, and are stronger within iso-orientation domains than pinwheel centers. Model simulations showed that these relations emerge when two robust intra-cortical computations – distance-weighted excitation from oriented neurons, and local divisive-inhibition from unoriented neurons – are applied with identical parameters to different orientation neighborhoods in cortex. Excitation enhances narrower tuning, cross-orientation suppression and response maximum in iso-orientation domains, as compared to pinwheel centers. Inhibition serves to make iso-orientation domains more sensitive to small contrasts, and more compressive to high contrasts, as compared to pinwheel centers. We conclude that pooled cortical outputs from iso-orientation domains and pinwheel centers differ not only in orientation diversity/selectivity but also in linearity of contrast response and suppression of responses to complex patterns. Image processing experiments demonstrated that outputs from narrow-tuned iso-orientation cells could be used in extra-striate cortex to build cells selective to edges and contours, whereas outputs from broad-tuned pinwheel cells could build extra-striate cells sensitive to textures and patterns.

Acknowledgement: EY005253, EY007556, EY013312

34.24, *3:15 pm* **Why do the response properties of magnocellular and parvocellular neurons differ both in space and time?** Michele Rucci[1,2](mrucci@bu.edu), Martina Poletti[1], Jonathan Victor[3], Marco Boi[1]; [1]Department of Psychological & Brain Sciences, Boston University, [2]Graduate Program in Neuroscience, Boston University, [3]Brain & Mind Research Institute, Weill Cornell Medical College

Magnocellular and parvocellular neurons in the retina and lateral geniculate nucleus tend to prefer complementary spatial frequency ranges, with magnocellular neurons sensitive to lower frequencies than parvocellular ones. Interestingly, these neurons also exhibit different temporal preferences: magnocellular neurons tend to be more responsive to temporal transients than parvocellular neurons. Why do neurons sensitive to separate spatial frequency ranges also differ in their temporal characteristics? To address this question, we combined three approaches: spectral analysis of retinal input, neural modeling, and visual psychophysics. We recorded eye movements at high resolution while human observers freely examined pictures of natural scenes and examined how different types of eye movements affect the frequency content of luminance signals on the retina. We made predictions of contrast sensitivity by passing these signals through linear-nonlinear neural models and a standard decision stage. Finally, we compared the predictions to psychophysical measurements obtained with an apparatus that allowed for control of retinal image motion. We found that saccades and fixational eye movements lead to strikingly different transformations of spatial patterns into temporal modulations. As a consequence, detection of a low spatial frequency stimulus tends to be more reliable immediately following a saccade than later during fixation, whereas a high spatial frequency stimulus maintains similar levels of detectability throughout fixation. In a model that optimally integrates information during post-saccadic fixation, these dynamics predict an oculomotor-driven coarse-to-fine dynamics of contrast sensitivity, which we confirm psychophysically. Magnocellular neurons capture the transient modulations that saccades produce from low spatial frequencies, while parvocellular neurons capture the sustained modulations that fixational movements produce from high spatial frequencies. Thus, a coupling between spatial and temporal response characteristics similar to that observed in retinal ganglion cells emerges as an experimentally-confirmed prediction of a model of contrast sensitivity that takes oculomotor transients into account.

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34.25, *3:30 pm* **Perceptual and neural deficits in processing naturalistic image structure in amblyopia** Lynne Kiorpes[1](lynne@cns.nyu.edu), Angela Voyles[1], Corey Ziemba[1], J. Anthony Movshon[1]; [1]Center for Neural Science, New York University

Amblyopia is a developmental visual disorder that affects visual acuity and contrast sensitivity. Many amblyopes also suffer losses on higher-order visual tasks, such as contour integration and form discrimination, the neural bases of which remain unexplained. While neural abnormalities have been found at the level of V1 in amblyopia, it is likely that there are significant processing defects in higher-order visual areas. We recently reported that sensitivity to the higher-order statistics of naturalistic texture images is a signature of processing in area V2 (Freeman, Ziemba et al., 2013). We therefore asked whether amblyopes are poorer at detecting these statistics and whether there is a corresponding neural deficit in V2. We tested 5 amblyopes (4 macaques,1 human) using a spatial 2AFC. They discriminated texture patterns that retain variable amounts of the higher-order statistical structure of original natural images from noise images that retain only the orientation and spatial frequency content. All amblyopes were impaired on the discrimination when viewing with their amblyopic eyes. To investigate whether there was a related neural deficit, we measured neuronal sensitivity to naturalistic structure in 5 amblyopic macaques under anesthesia. We used 96-electrode "Utah" arrays to record multiunit activity and found that V2 sites driven by the amblyopic eye showed a reduced ability to distinguish naturalistic images from their noise counterparts relative to the fellow eye; V1 neural activity was similar for amblyopic and fellow eyes. We conclude that amblyopia modifies the processing of naturalistic visual structure.

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34.26, *3:45 pm* **An Image-Based Multi-Channel Model for Light Adaptation** Felix Wichmann[1,2,4](felix.wichmann@uni-tuebingen.de), Nicole Eichert[1,3], Heiko Schütt[1,3]; [1]Neural Information Processing Group, Faculty of Science, University of Tübingen, Germany, [2]Max Planck Institute for Intelligent Systems, Empirical Inference Department, Tübingen, Germany, [3]Graduate Training Centre of Neuroscience, University of Tübingen, Germany, [4]Bernstein Center for Computational Neuroscience Tübingen, Germany

The human visual system is sensitive to luminances ranging from 10-6 to 108 cd/sqm (Hood & Finkelstein, 1986, Handbook of Perception and Human Performance, Vol 1). Given the more limited dynamic range of the photoreceptors and subsequent neurons, effective light adaptation must thus be an essential property of the visual system. In an important study Kortum & Geisler (1995, Vision Research) measured contrast increment thresholds for increment-Gabor probes on flashed backgrounds in the presence of steady-state backgrounds, exploring how the spatial frequency of the increment-Gabor affects thresholds, i.e. how light adaptation and spatial vision interact. In addition to their experiments, Kortum & Geisler presented a successful model in which the incoming signal undergoes multiplicative and subtractive adapting stages followed by non-linear transduction and late noise. Here we significantly expand and modify their model: First, our model is image-based and thus accepts any image as input, whereas the original model is only applicable to the putative scalar activations of sine wave stimuli. Second, our model has a single set of parameters for the multiplicative and subtractive adaptation stages, followed by a multi-scale pyramid decomposition (Simoncelli & Freeman, 1995, IEEE International Conference on Image Processing, Vol. III). The spatial frequency dependence of the thresholds is modelled via the DC components' selective influence on the variance of the late noise in the decision stage of the model. In the original model by Kortum & Geisler the parameters of the multiplicative and subtractive adaptation stages are all spatial frequency dependent, which is problematic if one believes adaptation to happen very early in the visual system, before the signal is split into separate spatial frequency channels. Our image-based multi-channel light adaptation model not only accounts well for the data of Kortum & Geisler (1995), but in addition captures, for example, the effects of test patches of different size (Geisler, 1979, Vision Research).

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34.27, *4:00 pm* **The pyramid of visibilty** Andrew Watson[1](abwatson@me.com), Albert Ahumada[1]; [1]NASA Ames Research Center

A fundamental limit to human vision is our ability to sense variations in light intensity over space and time. A half century ago, these limits were first described systematically in a series of three seminal papers. de Lange (1958), van Nes and Bouman (1967), and Robson (1966) measured the visibility of temporal, spatial, and joint spatio-temporal sinusoidal variations. Additionally, the first two papers described the dependence of sensitivity on the the light level from which the deviations occurred. These results provided an enduring foundation for all subsequent studies of contrast sensitivity. We have recently reanalyzed these reports and discovered a remarkable simplification. At moderate to high frequencies the log of contrast sensitivity is a linear function of spatial frequency, temporal frequency, and the log of adapting luminance. As a surface in the space defined by spatial and temporal frequency, log sensitivity thus forms a rectangular pyramid. Almost 40 years ago, Kulikowski (1971) also noted these linear relationships in his own data, but his result appears not to have been widely appreciated. Elsewhere we have described the intersection of this surface with a plane at a contrast of 1 as the "window of visibility." (Watson, Ahumada & Farrell 1986; Watson 2013). The new linear formulation allows us to describe the complete surface as the "pyramid of visibility." The height of the pyramid rises linearly with the log of adapting luminance. As a result, the window of visibility is always a diamond that grows and shrinks, linearly, with the log of adapting luminance. This result has both theoretical significance and practical utility. The independence of spatial, temporal, and light level effects constrains models of visual processing, while the limits defined by the pyramid of visibility determine the ultimate spatial and temporal resolution required in electronic displays of static or moving imagery.

Acknowledgement: NASA SHFE Program

Scene Perception

Sunday, May 15, 5:15 - 7:15 pm
Talk Session, Talk Room 1
Moderator: Russell Epstein

35.11, *5:15 pm* **Investigating cortical feedback of objects and background scene to foveal and peripheral V1 using fMRI** Matthew Bennett[1](m.bennett.2@research.gla.ac.uk), Lucy Petro[1], Lars Muckli[1]; [1]Centre for Cognitive Neuroimaging, University of Glasgow

When discriminating abstract objects isolated in peripheral visual field, object information can be detected in non-stimulated foveal but not peripheral cortex (Williams et al., 2008). Conversely, complex natural scene information can be detected in non-stimulated peripheral cortex (Smith & Muckli, 2010; Muckli et al. 2015). This demonstrates cortical feedback contributions to object and scene representation in V1. Whether object and scene feedback are automatically directed to foveal versus peripheral V1, or if this is due to varying stimulus complexity/naturalism remains unknown. We addressed this question using computer-generated images of objects embedded in naturalistic scenes. Nine subjects underwent block-design fMRI (3T). Eight naturalistic computer-generated images variously combined objects and background scenes (Figure 1). The central portion and upper-right quadrant were occluded, preventing feed-forward stimulation of the ROIs, allowing isolation of feedback signals. Subjects discriminated either the scene or object. Multivoxel patterns (TR 2s; voxel-size 2mm3) from the ROIs were entered into support vector machine (SVM) classifiers. Bootstrapping determined above-chance group-level classification. In fovea (Figure 2), we classified object presence regardless of task (55.7%, 53.8%, collapsing task: 56.5%). Classifying object identity was only possible when collapsing task (55.9%). Also in fovea, we classified scene information during the scene task (56.7%) and when collapsing task (59.5%) but not during object task (52.2%). Therefore, the non-stimulated fovea contains object and task-dependent scene information. In periphery (Figure 3), no object information was detected. We classified scene information during object task (57.4%) and when collapsing task (55.3%), but not during scene task (54.6%). Therefore the non-stimulated periphery contains only scene information. Our data suggest specialisation in cortical feedback to V1 cortex: scene information is fed-back diffusely to foveal and peripheral V1, whereas object feedback is directed to foveal cortex – possibly for high resolution scrutiny (Williams et al., 2008; Levy et al., 2001).

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35.12, *5:30 pm* **Neural coding of navigational affordances in visual scenes** Michael Bonner[1](michafra@mail.med.upenn.edu), Jack Ryan[1], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania

An essential component of visually guided navigation is the ability to perceive features of the environment that afford or constrain movement. For example, in indoor environments, walls limit one's potential routes, while passageways facilitate movement. Here we examine the cortical mechanisms that encode such navigational features. In two fMRI experiments we test the hypothesis that scene-selective cortices represent the navigational affordances of local space. In the first study, subjects viewed images of artificially rendered rooms that had identical geometry as defined by their walls, but varied on the number and position of open passageways leading out of them. The layout of these passageways defined the principal navigational affordances in each scene. We used multivoxel pattern analysis to identify representations of navigational layout that were invariant to other visual features, including surface textures and visual clutter. This analysis revealed that the occipital place area (OPA), a scene-selective region near the transverse occipital sulcus, contained fine-grained representations of navigational layout that could be decoded across variations in visual appearance even though the local geometry was the same for all scenes. Given our tightly controlled, artificial stimuli, an important question was whether these conclusions would generalize to more complex, naturalistic scenes. We addressed this in the second study by using images of real-world indoor environments. To identify navigational affordances, we asked independent raters to indicate the paths they would take to walk through each scene. We then used representational similarity analysis of fMRI data obtained during an orthogonal category-judgment task to identify brain regions that encode these navigational affordances. Once again we found representations of navigational layout in the OPA, demonstrating that this effect generalizes to naturalistic scenes with heterogeneous visual and semantic properties. These findings indicate that the OPA supports a critical aspect of scene perception—the representation of navigational space.

35.13, *5:45 pm* **Conceptual representations of scene categories in prefrontal cortex transcend sensory modalities** Yaelan Jung[1](jung.yaelan@gmail.com), Bart Larson[2], Dirk Walther[1]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, University of Pittsburgh.

Our natural environment is composed of a rich tapestry of sights and sounds. How is this multimodal information from a real-world setting processed in our brain, forming a representation of a particular environment? A number of studies have shown that in the visual domain, several visual properties related to scene categories are identified and processed in scene-selective areas in the visual cortex. Moving beyond the purely sensory representations of scene categories, we are here looking for a more abstract and conceptual representation of scenes that transcends sensory modalities. To this end, we had participants look at scene images or listen to scene sounds while their neural activity was recorded in an MRI scanner. Using multi-voxel pattern analysis, we were able to decode scene categories not only in sensory cortex (image categories in visual cortex and sound categories in auditory cortex) but also in prefrontal cortex, which is known to engage in high-level cognitive functions. Furthermore, the scene representation in the middle and inferior frontal gyrus generalized across sensory modalities, as shown by successful cross-decoding of scene categories between images and sounds. Finally, we compared the error patterns of the neural decoder to those of human categorization from a separate behavioral experiment. We found significant agreement between behavioral errors and the errors of the neural decoder in the inferior and middle frontal gyrus, which shows that the information that humans use for categorical judgment is represented in these regions. These results indicate that there exists a conceptual level of scene representations in prefrontal cortex, which reflects human behavior and does not rely on any one sensory modality. To our knowledge, this is the first time that such a cross-modal conceptual representation of real-world scenes has been measured explicitly.

35.14, *6:00 pm* **Neurodynamics of visual and auditory scene size representations** Santani Teng[1](santani@mit.edu), Radoslaw Cichy[1], Dimitrios Pantazis[2], Verena Sommer[1,3], Aude Oliva[1]; [1]CSAIL, Massachusetts Institute of Technology, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology, [3]Amsterdam Brain and Cognition Centre, University of Amsterdam

Perceiving the geometry of space is a core ability of most animals, mediating spatial cognition between lower-level perceptual processing and navigation-related processing. Information about spatial layout, i.e. the boundaries and size of an environment, is multisensory: the perceived extent of an indoor volume can come from the visual perception of boundaries or be indexed by auditory reverberations. Although the cortical loci of visual spatial layout perception are well described, the dynamics of human spatial cognition in vision and audition remain elusive, as the neuronal markers indexing spatial processing are unknown. Here, we report the electrophysiological signatures of spatial layout perception in visual and auditory modalities. We conducted two experiments. First, in the visual domain, we recorded magnetoencephalography (MEG) in 15 healthy participants who viewed 48 images of scenes differing in size and other factors. Second, in the auditory domain, we recorded MEG in 14 participants who heard 9 reverberant sounds differing in the space size they indexed and the sound sources they contained. We used multivariate pattern classification and representational similarity analysis to analyze both experiments. For vision, we identified a marker of scene size perception around ~250ms, independent of low-level image and semantic properties (i.e. luminance, contrast, clutter, semantic category), thus indexing neural representations robust to changes in viewing conditions as encountered in real-world settings. For audition, we identified an auditory signature of scene size with a more extended temporal profile, peaking at ~385ms, and robust to variation in sound sources as well. These results constitute the first descriptions of an electrophysiological signal for spatial scene processing in humans in both visual and auditory domains. They elucidates the temporal dynamics with which the human brain extracts spatial information from the environment, and opens the door to further investigation of the timing of space perception.

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35.15, *6:15 pm* **Meaningful feedback to occluded V1 is improved by increasing local information in the surround** Yulia Revina[1](y.revina.1@research.gla.ac.uk), Lucy Petro[1], Cristina Denk-Florea[1], Sebastian Blum[2], Nikolaus Kriegeskorte[3], Lars Muckli[1]; [1]Centre for Cognitive Neuroimaging, University of Glasgow, UK, [2]University of Osnabrück, Germany, [3]MRC Cognition & Brain Sciences Unit, Cambridge, UK

Most input to V1 is non-feedforward, originating from lateral and feedback connections. Using functional magnetic resonance imaging (fMRI) and multivariate pattern analysis (MVPA), Smith & Muckli (2010) showed that non-feedforward stimulated regions of V1 (i.e. responding to an occluded image quadrant) contain contextual information about the surrounding image, fed back from higher visual areas. In two experiments we investigated what features of the surround are necessary for meaningful feedback to non-stimulated V1. In Experiment 1, we studied how decreasing surrounding scene information affects feedback. Participants viewed two natural scenes where we modulated the visibility of the surround using a grey mask punctured with Gaussian bubbles of varying sizes, (Gosselin & Schyns, 2001). In Experiment 2, we investigated whether feedback signals carry information about the full configuration of the scene (global) or information close to the occluded quadrant (local). Participants viewed stimuli composed of four Gabors oriented at either 45°or 135°, one in each quadrant. There were four possible global structures: Right (all Gabors at 45°), Left (all 135°), Diamond, and X-shape. In both experiments, each stimulus was presented in feedback (occluded quadrant) and feedforward (corresponding quadrant visible) conditions. We then decoded the stimuli using V1 voxels relating to the lower right quadrant. Results showed that larger bubbles lead to better decoding, suggesting that a large amount of surrounding information needs to be visible for meaningful feedback to non-stimulated V1. Secondly, we found that feedback in the occluded quadrant mainly carries information about the local surround, rather than the global structure of the stimulus. Finally, both experiments showed that feedback signals from the surround interact with feedforward information in the quadrant.

Acknowledgement: ERC StG 2012_311751-Brain reading of contextual feedback and predictions (Lars Muckli) & BBSRC DTP Studentship (Yulia Revina)

35.16, *6:30 pm* **Perception of dynamic scenes: What is your Heider capacity?** Farahnaz Ahmed Wick[1](farahnaz@gmail.com), Sahaj Garg[2], Abla Soce[3], Jeremy Wolfe[3]; [1]University of Massachusetts Boston, [2]Bridgewater-Rartan High School, [3] Harvard Medical School and Brigham & Women's Hospital

The classic animation experiment by Heider and Simmel (1944) demonstrated our strong tendency to perceive and remember interactions of simple geometric shapes in the form of a narrative. In their animation, three simple shapes move around on the screen. Observers almost inevitably interpret them as rational agents with intention, desires and beliefs ("That mean green square!"). Much subsequent work on dynamic scenes has identified basic visual properties that can make shapes seem animate. Here, we investigate the limits on our ability to use narrative to understand an animated scene. We created 30-second Heider-style cartoons containing 3 to 9 items whose trajectories were generated by a simple set of rules (e.g. red squares are biased to move toward green circles). For each set size, four distinct cartoons were designed based on a different combination of these rules. In the first stage of the experiment, we asked ten Amazon Mechanical Turk participants to write short narratives for each cartoon. These narratives were scored for accuracy by three lab assistants. For each cartoon, the five highest scored narratives were used in the next stage of the experiment. A new group of participants (N= 48) were shown a cartoon and then presented with a narrative: either one written for that specific cartoon or one written for a different cartoon with the same objects. Participants judged how well the description fit the cartoon on a scale from 1(clearly does not fit) to 5(clearly fits). ROC curves generated from the rating scale data show good performance with three objects ($d' = 1.55$) but poor performance for larger set sizes (all $d' < 0.8$). Apparently, our "Heider capacity" falls off dramatically after 3 objects, suggesting a limit related to the visual working memory and/or motion tracking limits. Such limits may impact interpretation and recall of real-world dynamic scenes.

35.17, *6:45 pm* **Change-related weighting of statistical information in visual decision making** Jozsef Fiser[1](fiserj@ceu.edu), Jozsef Arato[1], Abbas Khani[2], Gregor Rainer[2]; [1]Department of Cognitive Science, Central European University, [2]Department of Physiology/Medicine, University of Fribourg

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Perceptual decisions are influenced not only by short-term history (e.g. adaptation, repetition, sequential effects), but also by statistics of events from many decisions ago. Nevertheless, such long-term effects are often ignored or, at best, described as positive long-term priming. Recent findings, however, suggest a complex interaction between short and long-term statistics in modulating perceptual decisions, but these effects are not well understood. We conducted six 2-AFC visual shape discrimination experiments, in which we not only independently manipulated the appearance probabilities (APs) of abstract shapes over short and long time ranges, but also tested the effect of dynamically changing these probabilities. To assess the interaction between subjective uncertainty and past information, one of two possible shapes appeared in varying levels of Gaussian noise on each trial. First, we report that, in ambiguous trials, instead of simply being primed by earlier APs, subject made decisions so that it would compensate the discrepancy between recent and earlier APs. This behavior led to the paradoxical result that a stimulus presented more frequently in recent past was significantly not preferred if it was less frequent in the distant past. Second, we found that this compensatory mechanism did not take effect when the difference in APs between long past and recent times was introduced gradually rather than abruptly. This led to the paradox of false and lasting negative compensation when there was no difference in APs between past and present due to a momentary abrupt shift followed by a gradual return. We replicated our key human finding with behaving rats, demonstrating that these effects do not rely on explicit reasoning. Our results suggest that instead simply following the rule of gradually collected event statistics, perceptual decision making is influenced by a complex process in which statistics are weighted by significance due to detected environmental changes.

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35.18, *7:00 pm* **Did you see the milk in the bathroom? The developmental trajectory of eye movement control by scene semantics in preschoolers** Sabine Öhlschläger[1,2](oehlschlaeger@psych.uni-frankfurt.de), Melissa Vo[1,2]; [1]Scene Grammar Lab, Goethe University, Frankfurt, Germany, [2]Center for Research on Individual Development and Adaptive Education of Children at Risk (IDeA), Frankfurt, Germany

Would you look for the milk in the bathroom? Probably not, because adults are effective scene searchers. When adults are presented with scenes containing an object that does not fit the meaning of the scene (milk instead of shampoo in the bathroom), their gaze dwells longer on this object than if it was consistent, reflecting their knowledge of scene semantics. When does this semantic congruency effect emerge during development? To answer this question we recorded eye movements of three- and four-year old children (n=15) as well as adults (n=9) while they were viewing photographs of daily-life scenes in a paradigm with gaze-contingent stimulus presentation. Children showed longer dwell times for semantically incongruent than congruent objects independent of their age. This semantic congruency effect was driven by a larger number of fixations on the critical object rather than longer fixation durations. The comparison to adults revealed an increase of the semantic congruency effect in dwell times across age groups. Moreover, only for adults the average duration of fixations tended to differ between congruency conditions. As real-world validation we asked children and adults to put 52 objects into a dollhouse, equipped with only one reference object per room. Here, younger children preferred to put more objects of one type of category together (i.e., various cupboards next to the reference wardrobe in the child room) compared to older children and adults, who tended to distribute them across rooms. While the eye tracking data imply that already by the age of three, children show indices of semantic scene knowledge, the results of the dollhouse task suggest differences in developmental processes within this age group. Future studies should include children of a younger age to identify the entire range of important milestones in the development of scene knowledge.

Acknowledgement: This work was funded by DFG grant VO 1683/2-1 to MLV.

Sunday PM

Multisensory Processing

Sunday, May 15, 5:15 - 7:15 pm
Talk Session, Talk Room 2
Moderator: Lore Thaler

35.21, *5:15 pm* **Young Children Can Combine Audio-Visual Cues Near-Optimally After Training** James Negen[1](jnegen@gmail.com), Hannah Roome[1], Marko Nardini[1]; [1]Psychology Department, Durham University

We studied how children 8-9 years old respond to simultaneous training of two different perceptual cues. Previous research without training has shown that children at this age will fail to take an appropriate precision-weighted average of an auditory and visual cue (e.g. Gori, Sandini & Burr, 2012). We wanted to know if children at 8-9 years are fundamentally incapable of precision-weighted averaging or if they just require training. We put six children in a virtual reality environment with a curved wall in front of them and a 'magic wand'. They were played a spatialized sound, visually shown a probability distribution sitting on top of the wall, or both. They had to use these cues to try and point to a hidden target on the top part of the wall. The width of the visual probability distribution varied from trial to trial. They were always shown the location of the actual target afterwards. Data were analysed by Bayesian model comparison. The 'optimal' model, which takes a reliability-weighted average of the two single cues on each trial, has the most support on balance. Its main competitor is an extremely-similar model with a small systematic mis-weighting of the two cues. Models that rely on one cue or just switch back and forth between the two cues are unlikely explanations (Bayes factors < .05) for all but one child. A model that does not account for trial-to-trial changes in reliability of the visual cue is also a poor fit overall. We conclude that children 8-9 years old are actually capable of quickly learning to weight and combine perceptual cues, perhaps with a small mis-weighting, at least under these circumstances. We are investigating how this depends on the nature of the feedback and the type of visual cue.

Acknowledgement: James S. McDonnell Foundation

35.22, *5:30 pm* **Is a newly learnt sense immediately combined with vision?** Marko Nardini[1](marko.nardini@durham.ac.uk), James Negen[1], Hannah Roome[1], Lore Thaler[1]; [1]Dept of Psychology, Durham University, UK

In many perceptual tasks, observers minimise random error by reliability-weighted averaging (e.g. Ernst & Banks, Nature 2002). Late development of this ability in childhood (e.g. Nardini et al, Curr Biol 2008; Dekker et al, Curr Biol 2015) suggests that it requires either considerable experience with specific cues or maturation of the nervous system. To study the role of experience, we asked if adults learning a new sense would immediately combine it with vision. Ten adults judged the distance to a fish hidden in a virtual "sea". In 75 initial trials they were trained in using a new sense, echolocation – clicks and their echoes, coming from a virtual surface at the distance of the fish. In 175 subsequent trials they localised the fish using echoes, a noisy visual cue (bubbles), or both. The visual cue's variance varied trial-to-trial, tracking on average the echo cue's estimated variance. The fish was shown after each trial. 7/10 subjects were above chance at using the new cue. Their data were analysed by Bayesian model comparison. For most (5/7), single-cue models (switching or vision-only) were better fits than cue combination models – including those that do not reweight by reliability or that systematically mis-weight – by a large margin (Bayes factors > 20). Author JN and one final participant were best fit by an optimal combination model (BF > 100 over the best single-cue model). Most participants who learned a new sense did not immediately combine it with vision. This suggests that extended experience with specific cues underlies human cue combination abilities. However, optimal combination after very little, or relatively little (author JN) experience was also seen. In future research we will ask which aspects of single-cue learning (e.g. bias) predict cue combination, whether with practice more participants learn to combine cues, and what intermediate stages exist.

Acknowledgement: James S McDonnell Foundation

35.23, *5:45 pm* **The Sight-Audition Farness Effect (SAFE): Observation Distance Systematically Changes Umpire versus Fan Judgments about Baseball Runners Being Out or Safe** Michael McBeath[1](m.m@asu.edu), R. Krynen[1]; [1]Department of Psychology, Arizona State University

Introduction: This study examines if slowness of the speed of sound can systematically influence multisensory precedence judgments, such as if a baseball base-runner visually reaches base before the auditory sound of the ball hitting the baseman's mitt. Because the speed of sound is only about 1100 feet per second, distant fans could judge the ball to arrive hundreds of msec later compared to a nearby umpire. Methods: 140 participants observed videos projected onto a gymnasium wall and made multisensory precedence judgments from 0, 100, or 200 feet. Participants judged which cue occurred first, visual ("safe") or auditory ("out") (no ties allowed). Experiment 1 used a visual flash versus auditory click, Experiment 2, colliding visual stimuli versus auditory click, and Experiment 3, films of base-runners with basemen catching balls. Results: Our findings verify that nearby observers exhibit a bias to favor sound occurring earlier, but at further distances tend to ignore the delay of sound reaching them. Thus, judgments were based largely on the order in which observers were exposed to the visual and auditory cues. This produced about a 100 msec change in threshold for each 100 feet more distant. The effect was mitigated in cases of colliding visual stimuli and actual baseball player videos when visual interception information was more apparent. Conclusions: We found observers exhibit a bias to favor auditory stimuli as occurring before visual stimuli (consistent with the slow speed of sound), but a tendency to not account for the delay of sound due to observation distance, with the offset-delay mitigated in more ecologically-valid conditions of visual interception. Our findings confirm that when distant visual information is impoverished, observers (such as fans making multisensory precedence judgments) typically do not fully account for acoustic delays due to the slow speed of sound, which could lead to arguments.

35.24, *6:00 pm* **Lip Movements Amplify Correlated Spectral Contours in Speech** John Plass[1](johncplass@u.northwestern.edu), Marcia Grabowecky[1,2], Satoru Suzuki[1,2]; [1]Psychology Department, Northwestern University, [2]Northwestern University Interdepartmental Neuroscience Program

Viewing articulatory lip movements can improve the detection and comprehension of congruent auditory speech. However, the specific audiovisual correspondences that underlie these crossmodal facilitation effects are largely unknown. We hypothesized that the perceptual system may exploit reliable natural relationships between articulatory lip motion and speech acoustics. In particular, analysis of four speakers (two female) revealed a strong correlation (all R2 > .9) between the horizontal width of the oral aperture and the height of the frequency of the second formant as the speakers expanded and contracted their lips to pronounce the syllables /wi/ and /yu/ (APA transcription). To test whether this dynamic relationship between mouth aspect ratio and second-formant frequency underlies crossmodal facilitation of speech perception, we produced artificial stimuli that reproduced the audiovisual relationship. Visual stimuli were dark ellipses on a light background whose width expanded or contracted over 350 ms, approximating the sigmoidal change in mouth width when people pronounce /wi/ and /yu/. We verified that these ellipses were not perceived as mouths. Auditory stimuli were 100-Hz-wide band-pass-filtered white noise whose mean frequency rose or fell between 500 and 3000 Hz, approximating the second-formant frequency change. Using a bias-free 2IFC auditory-detection task (in noise), we estimated 18 participants' detection thresholds for the frequency sweeps while they viewed ellipses with correlated horizontal motion, anti-correlated horizontal motion, or no motion (using interleaved QUEST staircases). To rule out the possibility of a more general non-speech-specific mechanism, we also included conditions in which ellipses expanded or contracted vertically. As predicted, only correlated horizontal motion significantly decreased auditory detection thresholds relative to the static control. Anti-correlated and vertical motion produced no reliable changes. Together, these results suggest that the perceptual system exploits natural relationships between articulatory lip motion and vocal acoustics to facilitate speech perception.

35.25, *6:15 pm* **A causal inference model of multisensory speech perception provides an explanation for why some audiovisual syllables but not others produce the McGurk Effect** John Magnotti[1](john.magnotti@gmail.com), Michael Beauchamp[1]; [1]Department of Neurosurgery and Core for Advanced MRI, Baylor College of Medicine

Audiovisual speech integration combines information from auditory speech (talker's voice) and visual speech (talker's mouth movements) to improve perceptual accuracy. However, if the auditory and visual speech emanate from different talkers, integration decreases accuracy. Therefore, a key step in audiovisual speech perception is deciding whether auditory and visual speech have the same cause, a process known as causal inference. A primary cue for this decision is the disparity between the auditory and visual speech content, with lower disparity indicating a single cause. A well-known multisensory illusion, the McGurk Effect, consists of incongruent audiovisual speech, such as auditory "ba" + visual "ga" (AbaVga), that is integrated to produce a fused percept ("da"). This illusion raises at least two questions: first, given the disparity between auditory and visual speech, why are they integrated; and second, why does the McGurk Effect occur for some syllables (e.g., AbaVga) but not other, ostensibly similar, syllables (e.g., AgaVba). We describe a Bayesian model of causal inference in multisensory speech perception (CIMS2) that calculates the percept resulting from assuming common vs. separate causes; computes the likelihood of common vs. separate causes using content disparity; averages the common and separate cause percepts weighted by their likelihood; and finally applies a decision rule to categorize the averaged percept. We apply this model to behavioral data collected from 265 subjects perceiving two incongruent speech stimuli, AbaVga and AgaVba. The CIMS2 model successfully predicted the integration (McGurk Effect) observed when human subjects were presented with AbaVga and the lack of integration (no McGurk Effect) for AgaVba. Without the causal inference step, the model predicted integration for both stimuli. Our results demonstrate a fundamental role for causal inference in multisensory speech perception, and provide a computational framework for studying speech perception in conditions of varying audiovisual disparity.

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35.26, *6:30 pm* **Low-level auditory and visual features can be decoded across early sensory cortices.** Joo Huang Tan[1](jootan@u.duke.nus.edu), Po-Jang Hsieh[1]; [1]Neuroscience and Behavioural Disorders Programme, Duke-NUS Graduate Medical School Singapore

Hierarchical models of sensory processing suggest that incoming low-level sensory features are first processed in their respective unisensory cortices. Information is then processed and integrated as it gets passed serially along the hierarchy. However, recent evidence has suggested that the cortex is not strictly organized in a hierarchical manner. Here we ask the question: are neural representations of low-level visual and auditory features constrained to their own early sensory cortices? In this fMRI study, we sought to elucidate brain regions that contain pattern information that discriminated between different dimensions of low-level auditory and visual features across the brain. The four low-level features selected for this study were visual spatial frequency, grating orientation, auditory amplitude modulation rate, and pitch. During the experiment, subjects were presented with the visual and auditory stimuli alternately in separate experimental blocks. We demonstrate that patterns of activation elicited by these low-level sensory features are not simply constrained to their respective sensory cortices. Instead, the neural representations of these low-level sensory features can be decoded across many regions of the cortex including other modalities' sensory cortices. More importantly, we have demonstrated that the cross-modal signals in "unisensory" regions contain specific details of the different dimensions of another modality's low-level features. These results suggest that early sensory processing involves a larger network of brain regions than previously thought. It also suggests that multisensory interactions may be involved at the early stages of sensory processing.

35.27, *6:45 pm* **Dependence of visual-vestibular conflict detection on temporal synchrony** Paul MacNeilage[1,2](p.macneilage@gmail.com), Isabelle Garzorz[1,2]; [1]German Center for Vertigo, Univeristy Hospital of Munich, [2]Graduate School of Systemic Neurosciences, Ludwig Maximilian University

Detecting sensory conflict implies a comparison process akin to cross-modal discrimination which can be modelled as a subtraction of sensory estimates resulting in a difference distribution. This distribution has mean equal to the difference of compared signal means and variance equal to the sum of compared signal variances. The mean provides an estimate of the amount of conflict and the variance determines a limit on cross-modal discrimination (and conflict detection). Here we show that visual-vestibular discrimination performance approaches this limit when cues are presented sequentially. However, when cues are presented simultanouesly, cross-modal discrimination is impaired. Experiments were conducted using a virtual reality set-up consisting of a hexapod motion platform and stereo visual display. The stereo visual stimulus consisted of red spheres (diameter = 0.6 cm; density = 0.004 spheres/cm^3; clipping planes: near = 25 cm, far = 65 cm) and a head-fixed fixation point. Yaw rotations had a raised cosine velocity profile of constant duration (0.8 s) and displacement of 4 deg for the reference movement (peak velocity = 10 deg/s). Two single-cue conditions (2IFC) measuring visual and vestibular self-motion variance by means of an adaptive staircase procedure were the basis for predictions about variances in two additional conditions in which visual stimuli had to be compared with vestibular stimuli either sequentially (2IFC) or simultaneously. In the simultaneous condition subjects had to indicate whether the simultaneously presented visual scene moved with or against their own physical motion in world coordinates. We hypothesize that impaired discrimination during simultaneous presentation occurs because temporal co-occurrence increases the estimated probability that signals have a common origin, which leads to optimal cue integration at the cost of impaired conflict detection. We present a probabilistic model of these processes.

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35.28, *7:00 pm* **Humans implement nonlinear computations to achieve near optimality in the face of scalar variability.** Seth Egger[1,2](swegger@mit.edu), Mehrdad Jazayeri[1,2]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, MA, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology, MA

Humans seek to optimize sensory estimates by integrating (1) prior experience and (2) available sensory measurements. For example, when multiple cues are present, humans can linearly combine independent measurements according to their reliability. This linear weighting, however, does not optimize estimates of sensory quantities for which the noise scales with stimulus strength (scalar variability) such as elapsed time, numerosity and heaviness. For these stimuli, the optimal integration rule is significantly more challenging as it requires a multidimensional and highly nonlinear operation. We asked if humans can implement an optimal integration strategy in timing behavior for which noise is thought to scale with duration. Subjects performed a time interval reproduction task in which we controlled the number of measurements subjects made. On each trial, we visually presented either one or two identical sample intervals drawn from a fixed prior distribution, and asked subjects to accurately reproduce that interval. Production intervals were systematically biased toward the mean of the prior distribution demonstrating that humans used knowledge of the prior to improve their performance. Additionally, errors decreased with two measurements compared to one showing that subjects combined information from multiple measurements. We then used a Bayesian model to assess the optimality of subjects' performance. Although the model captured the overall trade off between bias and variance, the improvement furnished by an additional measurement fell short of the model predictions. This modest sub-optimality motivated us to ask whether an alternative model that combines measurements linearly accounts for the suboptimal behavior. However, the improvement in performance almost invariably exceeded the predictions of linear integration, suggesting humans integrate interval measurements according to a nonlinear rule. Given the prevalence of scalar variability in perception and cognition, our results have far-reaching implications for the brain's capacity to integrate sensory information in the control of behavior.

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Attention: Temporal

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.3001 **The half-time groove of divided attention: differences in EEG and decoding power spectra when attending to one vs. two items** Sébastien Crouzet[1,2](seb.crouzet@gmail.com), Rufin VanRullen[1,2]; [1]Université de Toulouse, France, [2]CNRS-CerCo, UMR 5549, Toulouse, France

Recent research indicates that sustained attention could in fact process information rhythmically, as a sequence of successive cycles with its own intrinsic frequency. When two items must be attended, an intriguing corollary of this "blinking spotlight" notion could be that the successive cycles are directed alternately to each target; as a result, each item would effectively be sampled at half the intrinsic rate of attention. Here, we tested this prediction in two experiments. In an endogenous attention task, subjects (n=8) covertly monitored one or two peripheral images (one house, one face) in order to detect a brief contrast change. In the sustained occipital EEG power, attending to two vs. one item resulted in a relative increase around 4Hz and a relative decrease around 10-11Hz. In a second experiment, we tested if comparable oscillations could be observed in the stimulus-evoked EEG visual representational content. Subjects (n=9) saw a first peripheral image (house or face) displayed alone for 600ms, before a second one (face or house) also appeared for the same duration, but at a different peripheral location. In monkeys, a similar protocol was found to trigger low-frequency 5Hz oscillations in inferotemporal single-cell activity, reflecting competitive interactions between neural populations selective to the two objects (Rollenhagen & Olson, 2005). Using time-resolved MVPA on EEG evoked-responses, we were able to create item selective classifiers that constantly indicated which stimulus was on the screen (peak AUC=0.8 around 100 ms after image onset). The time-course of single-trial classifier decision values presented a relative peak around 11Hz when only one object was present, and around 4-5Hz when two objects were on the screen. Taken together, these results are compatible with a blinking spotlight of attention, sampling information periodically around 10-11Hz, and resulting in a half-frequency effective sampling (around 4-5Hz) when there are two items to attend.

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36.3002 **Orientation selective responses as measured with EEG track both featural and temporal attention enhancements** Vy Vo[1](vyaivo@gmail.com), Eduardo Herrera[2], John Serences[1,2]; [1]Neurosciences Graduate Department, University of California, San Diego, [2]Department of Psychology, University of California, San Diego

Both macaques and humans are capable of flexibly deploying their attention over time to track the temporal probabilities of a relevant stimulus (Coull & Nobre, 1998; Ghose & Maunsell, 2002; Janssen & Shadlen, 2005; Nobre, Correa & Coull, 2007; Rohenkohl et al., 2012). Although behavioral results in humans suggest that feature-based attention can be deployed with high temporal precision, fMRI studies have not been able to track the modulation of feature tuning in subsecond detail (Bueti et al., 2010; Warren, Yacoub & Ghose, 2014). In the present study, we use scalp electroencephalography to estimate orientation tuning functions over time while subjects monitored a flickering stimulus (30 Hz) for a brief orientation change target. Similar to previous studies, the probability of the target varied over time. Subjects reported the direction of the orientation change on trials where the change was present (50% of the time) and withheld a response on the remaining trials. We trained an orientation encoding model using the power and phase of the steady-state visual evoked potential (SSVEP) on change-absent trials (Garcia, Srinivasan & Serences, 2013). This technique exploits the spatial distribution of the SSVEP response across all electrodes to estimate orientation sensitivity changes over time, and was used to reconstruct orientation selective response profiles for the remaining half of the trials which contained a target. These orientation selective response profiles peaked just before the anticipated target time, revealing feature-selective temporal attention effects in human cortex.

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36.3003 **Processing speed modulation in rhythmic entrainment paradigms** Chiron Oderkerk[1](chiron.oderkerk@gmail.com), Signe Vangkilde[1], Anders Petersen[1], Claus Bundesen[1]; [1]University Of Copenhagen

Rhythm has often been demonstrated to facilitate both motor performance and perceptual processing within the auditory domain. Miller, Carlson, and McAuley (2013) represents one of the few examples of facilitated report accuracy of visual stimuli presented in synchrony with an entrained rhythm. In a series of studies, we investigated the effect of temporal expectancy on visual perception, induced by an auditory rhythmic entrainment paradigm ad modum Miller et al. To obtain estimates of perceptual performance unconfounded by motor components, we employed non-speeded accuracy-based measures. In the first experiment, participants were presented with a series of seven rhythmic tones, before being shown a single visual stimulus in, or out of synch with the entraining rhythm. Exposure durations of the stimuli were systematically varied and estimates of perceptual processing speed and the threshold for conscious perception were derived using computational modelling based on Bundesen's Theory of Visual Attention (TVA; 1990). Contrary to Miller et al. our findings indicated lower processing speeds only for stimuli presented earlier than expected. This indicates a ramping up of expectancy caused by a failure to control for foreperiod effects and supports findings by Vangkilde, Petersen, and Bundesen (2014), who showed that the speed at which visual stimuli were processed increased with temporal expectation. However, further studies in which we controlled for expectancy by varying the length of the entraining period, also did not show an accuracy benefit for visual stimuli presented in synch with an entraining rhythm. Our findings and the robust non-replication are discussed in relation to the existing rhythmic expectancy literature.

Acknowledgement: Marie Curie

36.3004 **A Poisson Random Walk Model for Response Time and Pure Accuracy Tasks** Steven Blurton[1](steven.blurton@outlook.de), Carsten Nielsen[2], Søren Kyllingsbæk[1], Claus Bundesen[1]; [1]University of Copenhagen, Department of Psychology, [2]University of Copenhagen, Department of Economics

Based on a simple 'what first comes to mind' rule, a Theory of Visual Attention (TVA; Bundesen, 1990) provides a well interpretable model account of visual attention that has been successful in explaining performance in perception and classification tasks. One classical domain of TVA has been tasks of divided attention which often involve partial or whole report of highly discriminable stimuli such as letters or digits. The primary variable of interest is the accuracy of report with response times (RT) being of little practical use. Based on this work we propose a model of visual identification of less discriminable single stimuli in both speeded RT and pure accuracy tasks. We assume that tentative classifications are made during the identification of a stimulus, by Poisson generators (Bundesen & Harms, 1999; Townsend & Ashby, 1983). In the special case of a categorization task with two alternatives, A and B, evidence accumulation then follows a simple random walk with exponentially distributed interstep times. Visual identification is made conclusively in favor of A once the number of tentative categorizations favoring A exceeds the number favoring B by a criterial number (the threshold for response A). When the target stimulus is followed by a mask, it is conceivable that neither the threshold for A nor B is reached before identification of the target is interrupted by the mask. Then, a response based on a 'what has the most evidence' rule is made (Kyllingsbæk et al., 2012). We fitted the model to data of both a speeded RT and a pure accuracy task collected in the same participants. The model provides a good description of RT distributions as well as accuracy rates with comparable Poisson rates across conditions. The RT model inherits favorable properties of TVA such as well interpretable parameters of the visual identification process.

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36.3005 **Dynamics of voluntary and involuntary temporal attention** Rachel Denison[1](rachel.denison@nyu.edu), David Heeger[1], Marisa Carrasco[1]; [1]Department of Psychology and Center for Neural Science, New York University

Purpose: To test the hypothesis that voluntary and involuntary temporal attention continuously interact to affect perceptual sensitivity. Temporal attention is the prioritization of visual information at specific points in

time, and can be either voluntary (goal-directed) or involuntary (stimulus-driven). How these types of attention interact to affect perception is essentially unknown. Methods: On each trial, two Gabor targets (T1 and T2) were presented successively at the same location. We manipulated voluntary temporal attention with an auditory pre-cue that instructed participants to attend to T1, T2, or both targets (neutral condition). We presumed that involuntary attention would be elicited by T1, and we measured the timecourse of its effects on T2 performance using a variable SOA (100-800 ms, in different sessions to ensure predictable timing). Each target was independently tilted clockwise or counterclockwise (at observers' thresholds). A response cue instructed participants to report the orientation of either T1 or T2. In valid trials, the pre-cue and response cue matched (75%); in invalid trials, they mismatched (25%). We developed computational models of attentional dynamics and stimulus processing and fit them to the behavioral data. Results: Accuracy was higher for valid than invalid cues for both targets at intermediate SOAs. Overall accuracy increased across SOAs for T1 and was U-shaped for T2. Models of the dynamics of voluntary and involuntary temporal attention parsimoniously explained attentional cueing timecourses, backward masking effects for T1, and "attentional blink"-like behavior for T2, either by (a) implementing competition between targets for attentional resources across time or (b) enhancing early-stage target representations, which biased later competitive interactions. Conclusion: Attending to one stimulus improves discrimination performance for that stimulus relative to other stimuli presented slightly earlier or later. This effect depends on the time interval between stimuli, which is consistent with joint effects of voluntary and involuntary temporal attention.

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36.3006 The speed of Voluntary Shifts of Attention Michael Jenkins[1](mjenki02@mail.bbk.ac.uk), Anna Grubert[1], Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London

Serial selection models of visual search assume that sequential shifts of attention between different objects can occur rapidly (~50ms) when they are guided by features of these objects. This assumption was recently confirmed with ERPs (Grubert & Eimer, in press). However, fully voluntary movements of attention may take considerably longer (~150-300ms; Horowitz et al., 2009). The present study investigated the speed of such purely endogenously driven attention shifts by examining the N2pc component of the event-related potential (ERP) as a marker of attentional object selection. Letters and digits in four different colours appeared in four locations. Participants had to report the alphanumeric category of the object (T2) that was in a specific location relative to another object in a known colour (T1). In this task, attention should be allocated first to T1 and then move to T2. Because T2 colour was unpredictable, attention shifts from T1 to T2 were not feature-guided, but had to be based on voluntary control processes. In Experiment 1, the direction of these shifts was determined on a trial-by-trial basis by the shape of T1. In Experiment 2, shift direction was pre-defined (clockwise or anticlockwise). The N2pc to T2 emerged around 100 ms later than the N2pc to T1 in Experiment 1, and around 150 ms later in Experiment 2. These results show that voluntary attention shifts are slower than feature-guided shifts, but can still be completed within less than 200 ms.

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36.3008 Perceived time fluctuates at around theta rhythm Shuhei Shima[1](shima@fechner.c.u-tokyo.ac.jp), Yuki Murai[1,2], Kenichi Yuasa[2,3], Yuki Hashimoto[2,4], Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo, [2]Japan Society for the Promotion of Science, [3]National Institute of Information and Communications Technology, [4]Graduate School of Interdisciplinary Information Studies

Attention distorts perceived time. This attentional modulation of perceived time can occur as the result of modulation of the encoded duration itself, changes to the onset of the encoded duration, or both. In the present study, we investigated the role of attention in sub-second duration encoding, and focused especially on the effect of changes to the onset time. The duration perception of ten participants was tested with a behavioral oscillation paradigm, in which performance in a detection task fluctuates as a function of cue-to-target intervals. It has been suggested that the behavioral oscillation reflected periodic attentional modulations in perception. In the training phase, the participants learned two standard durations: 325 ms and 775 ms. In the test phase, a brief attentional cue was presented followed by a target. The participants were instructed to answer whether the target duration was closer to which of the two standard durations. The attentional cue and the target were presented in the same visual field (valid condition) or in different visual fields (invalid condition). The cue-to-target intervals were varied by 25 ms, between 250 ms and 1050 ms. Seven target durations were evenly spread between 325 ms and 775 ms. The bisection point (the duration giving 50% "long" responses) was calculated for each cue-to-target interval. The bisection point in the valid condition fluctuated at around theta rhythm as a function of cue-to-target interval. Fitting to the single-frequency sine function and permutation testing confirmed statistically significant behavioral oscillation at the bisection point. The results indicate that attentional modulation of perceived time is at least partially due to onset-induced change to the encoded duration. The behavioral oscillations we observed in this study also suggest that periodic attentional modulation is involved in relatively complicated perceptual tasks such as duration perception.

Acknowledgement: 251190032, 24330208

36.3009 Time course of distractor suppression revealed by chronometry Hsin-Mei Sun[1](sun.hsinmei@gmail.com), Preeti Verghese[2], Joo-Hyun Song[1]; [1]Cognitive, Linguistic & Psychological Sciences, Brown University, Providence, RI, [2]The Smith-Kettlewell Eye Research Institute, San Francisco, CA

Highly salient objects, such as flashing, brightly colored hazard signs, typically attract attention. Salience-based models of attention predict that the probability of object selection increases as a monotonic function of perceptual salience. Accordingly, previous visual search studies have demonstrated that high-salience distractors lengthen target selection times compared to low-salience distractors. However, with this discrete measurement, it is unclear how distractor suppression evolves over time and whether perceptual salience of distractors modulates this time course. To address these questions, we developed a novel chronometry paradigm to probe the temporal evolution of distractor suppression for varying salience. Participants localized a shape-defined target with a keypress while trying to ignore salient color singleton distractors appearing on approximately half of all trials. There were two singleton distractor colors: low feature contrast (LFC, pink) and high feature contrast (HFC, blue), while all other objects were rendered in red. On each trial, three consecutive beeps were presented at intervals of 500 ms. The first beep signaled the start of a trial, followed by a search array at various stimulus-onset asynchronies (SOA, 100-700 ms, sampled every 100 ms). Participants were asked to respond synchronously with the third beep that occurred at 1000 ms. Proportion correct served as a measure of the effectiveness of distractor suppression as a function of SOA. We demonstrated that while distractor salience did not differentially interfere with target selection at short SOAs (< 600 ms), HFC distractors produced greater attentional interference than LFC distractors in mid SOA trials (~700 ms). Interestingly, the interference effect of HFC distractors decreased at longer SOAs (> 900 ms) while that of LFC distractors increased. Our results suggest that distractor suppression for LFC distractors occurs and decays faster compared to HFC distractors. Thus, paradoxically, it makes weakly salient distractors more disruptive when the stimulus-response latency is long.

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36.3010 Super-fast endogenous allocation of temporal attention Yaffa Yeshurun[1](yeshurun@research.haifa.ac.il), Shira Tkacz-Domb[1]; [1]University of Haifa

It well known that we can voluntarily allocate attention to a specific point in time at which we expect a relevant event to occur. In this study we examined the time course of this endogenous allocation of temporal attention with the constant foreperiod paradigm. In the 'contingent condition' of this paradigm, the foreperiod duration (i.e., the interval between the onset of a warning signal and the onset of the target) is constant within a block, but varies between blocks. Thus, within each block of this condition there was full temporal certainty. The target was a letter presented for a brief duration (16 ms), and the task was to identify the letter. Letter identification was not speeded. Unlike previous studies we included a wide range of foreperiods (75-2400 ms). Critically, to avoid effects of exogenous temporal attention we employed a warning signal that did not include an intensity change. Finally, the warning signal in the 'non-contingent condition' did not bear any temporal contingencies with the target (i.e., the point in time at which the target appeared and the point in time at which the signal appeared were randomly picked from completely independent distributions). Hence, in this condition there was no temporal certainty. We found significantly higher identification accuracy with than without temporal certainty. This finding supports the claim that the allocation of temporal attention to a specific point in time improves perceptual processing. Importantly, such effects of temporal attention were found even with the shortest foreperiod - 75 ms. This finding suggests that the allocation of endogenous temporal attention is extremely fast, faster than the allocation of endogenous spatial attention. Currently we are testing the other prevalent paradigm of temporal attention – the temporal orienting paradigm, with a similar range of foreperiods and a similar control for exogenous effects.

36.3011 Change detection and visual classification: two sides of the same coin
Bo Chen[1](bchen3@caltech.edu), Ming Jiang[2], Mason McGill[1], Qi Zhao[2], Pietro Perona[1]; [1]Computation and Neural Systems, California Institute of Technology, [2]Electrical and Computer Engineering, National University of Singapore

Change is certain, but the what, the where and the when are unpredictable. E.g. approaching animals need to be detected promptly, and also classified as friend or foe. What is the best way to carry out detection and discrimination jointly? How do humans do it? We compared subjects' performance in three tasks: (1) detection with unpredictable stimulus onset time, (2) discrimination with known stimulus onset time, and (3) dual task: discrimination with unpredictable stimulus onset time. Four subjects participated in a novel random-dot motion discrimination task, where a trial begins with incoherent random-dot motion and coherent motion appears after a random delay. For different tasks, observers were required to detect the onset of the signal and/or discriminate the motion direction. In our stimuli motion directions are not necessarily opposite, so we could vary independently the difficulty of discrimination and detection by controlling the motion strength (% coherence) and the motion directions. Our data show that discrimination is more difficult when signal onset is uncertain, suggesting that the additional detection task imposes an extra cost on the system. We developed three models of joint detection and discrimination: an optimal model (CD: classify-then-detect), and two simplified versions of the optimal model (DCP: detection-classification-in-parallel, and DCS: detection-classification-in-series). We compare the predictions of the three models to human data, and find that CD does not fit the data well, as it has no flexibility to switch off the discrimination component, and will overestimate the difficulty of the detection-only task. In addition, DCS produces the most consistent parameter estimates among different tasks. DCS is sub-optimal because it discards signal for discrimination until detection. Thus our findings indicate that the visual system may not be optimal from a purely information-processing point of view.

36.3012 Separate process for perceptual and numerical estimation of temporal average
Hiromi Sato[1,2](satoh@l.u-tokyo.ac.jp), Isamu Motoyoshi[3], Takao Sato[1]; [1]Department of Psychology, The University of Tokyo, [2]JSPS Research Fellow, [3]Department of Life Sciences, The University of Tokyo

Humans can estimate the global trend in dynamic events from a stream of information. To understand the mechanism underlying such estimation, we have previously examined human performance for judging the temporal average of orientation or motion direction of a Gabor patch whose orientation or phase smoothly fluctuated for several seconds (Sato et al., VSS 2013). Our reverse-correlation analysis revealed that observers' judgments on the temporal average strongly depends on stimulus features immediately before their decision making; a peak-end effect. In the present study, we applied this paradigm to numbers. In our procedure, 20 digits (0 to 9) were presented sequentially for 2 sec. During the presentation, the digits temporally varied pseudo-randomly following a Gaussian distribution with particular mean and variance. Observers were asked to judge whether the arithmetic average of digits was above 5 or below. The results showed that observers equally weigh information of entire stimulus presentation, indicating no peak-end effect. This was neither because digits varied discretely since judgments on the average of discretely changing orientation showed a clear peak-end effect, nor because digits were more complex visual patterns since judgments on the average of dynamic facial expression also showed a clear peak-end effect. These results indicate a possibility that perceptual and numerical estimations of temporal average are subserved by distinct mechanisms.

36.3013 Lag-1 sparing in accuracy and reaction time: The importance of masking
Hayley Lagroix[1](hlagroix@sfu.ca), Vincent Di Lollo[1], Thomas Spalek[1]; [1]Psychology, Simon Fraser University

Perception of the second of two rapidly sequential targets (T1, T2) is impaired when presented soon after the first (attentional blink; AB). In an exception, known as Lag-1 sparing, T2 performance is relatively unimpaired when it comes directly after T1. Lag-1 sparing is typically found when the dependent measure is T2 accuracy. In contrast, Lag-1 deficit is observed when the dependent measure is reaction time (RT; Lagroix, Di Lollo, & Spalek, 2015). A notable methodological difference between experiments that measured accuracy and those that measured RT was that T2 was followed by a mask in the former but not in the latter. In the present work, we demonstrate that Lag-1 sparing can be obtained with RT as the dependent measure, but only if T2 is followed by a mask. In contrast, when the dependent measure is T2 accuracy, Lag-1 sparing is in evidence whether or not T2 is masked. These results have implications beyond the phenomenon of Lag-1 sparing. They suggest that accuracy and RT are not always equivalent measures, and suggest that the AB may arise from postponement of T2 processing at more than one level within the system. This is inconsistent with extant theories in which the AB is said to occur at a single stage of processing.

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36.3014 Temporal attention selects compound representations in a strategic manner: Evidence from the attentional blink
Guy Snir[1](snirguy@gmail.com), Yaffa Yeshurun[1]; [1]University of Haifa

When two targets are embedded in a rapid serial visual presentation (RSVP) the ability to report the second target (T2) is impaired if it is temporally close to the first target (T1): The attentional blink (AB). This deficit diminishes when the targets appear consecutively, even if three targets are employed. However, T1 identification deteriorates (a cost) when trailing targets are spared from the blink. The present study evaluated a modification of classic 2-stage theories of the AB that addresses both sparing and cost effects. The modified theory suggests that sequential RSVP stimuli are represented together in volatile "snapshots" formed during a 1st stage of processing. These snapshots may be selected and sent to a limited-capacity 2nd stage of processing where stimuli are individuated and consolidated. Snapshot selection is subject to strategic constraints. With multiple-target RSVP, two opposing constraints are balanced: Early snapshot selection might prevent identification of later targets, while late snapshot selection might prevent early targets individuation. These principles suggest that T1 identification would deteriorate with successful identification of consecutive targets, and that snapshot selection timing will vary with target-distractor distribution. Experiment 1 tested this prediction using RSVP with 3 targets. Three types of streams were employed: T1T2T3, T1T2DT3, and T1DT2T3 (D=distractor). Timing of snapshot selection was estimated based on T2 and/or T3 identification accuracy. As predicted, regardless of stream type, T1 identification was better when earlier snapshots were selected. Additionally, later snapshots were observed with the T1T2T3 stream compared to other streams, and with T1T2DT3 stream compared to T1DT2T3 stream. In Experiment 2, temporal expectancies were manipulated using RSVP with 2 targets. In line with the theory, with long inter-target-intervals, which afford multiple snapshots, T2 identification was better when T1 was correctly identified, and vice versa with short inter-target-intervals. Interestingly, only T1 benefited from temporal uncertainty reduction.

36.3015 Implicitly learned temporal association between targets attenuates AB effect
Jeongho Park[1](jpark203@jhu.edu), Kristen Johannes[1], Matt Levine[1], Soojin Park[1]; [1]Cognitive Science Department, Johns Hopkins University

In the Attentional Blink (AB) effect, the identification of Target 2 (T2) in a stream is impaired when presented 200-500ms after Target 1 (T1). Recent studies suggest that higher-order relationships between targets (e.g., semantically associated pairs) modulate the AB effect (Potter et al., 2005; Ferlazzo et al., 2007). In this study, we ask whether an implicitly learned temporal association among targets modulates the AB effect. To test this question, we manipulated the temporal association between targets through statistical learning before an AB task. The experiment consisted of two phases: Training and Letter Detection (AB task). During training, all participants saw a stream of 1000 letters while performing a one-back task. Participants were randomly assigned to view a stream of letters in random order (Random group), or a letter stream with an embedded triplet structure (Statistical group) consisting of 12 random letters organized into four triplets with non-uniform transitional probabilities within and across triplets (e.g., A-K-T, F-J-N). After training, participants performed a letter detection task by reporting two letter targets among a stream of rapidly presented digits (ISI = 100ms). Critically, we manipulated, within subject, whether targets were drawn from the same (within-) or different (across-) triplets. For each trial type, T2 was presented downstream from T1 with lag of 2 or 8 intervening digits. Both groups showed a clear AB effect (Lag8 identification > Lag2). However, only the Statistical group showed a modulation of the AB effect for within-triplet trials compared to across-triplet trials: Lag2 accuracy for within-triplet trials was significantly higher than across-triplet trials in Lag2 ($t(14)=2.63$, $p< .05$), but not in Lag8 ($t(14)=0.86$, $p>.05$). The interac-

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tion between lag and condition was marginally significant. No such pattern was observed for the Random group. The results suggest that implicitly learned temporal structure among targets attenuates the AB effect.

36.3016 **Pre-stimulus inhibition of microsaccades in adults with and without ADHD as an index for temporal expectations** Yarden Dankner[1](y.dankner@gmail.com), Lilach Shalev-Mevorach[1,2], Marisa Carrasco[3,4], Shlomit Yuval-Greenberg[2,5]; [1]School of Education, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University, [3]Department of Psychology, New York University, [4]Center for Neural Science, New York University, [5]School of Psychological Sciences, Tel Aviv University

Introduction: Attention Deficit Hyperactivity Disorder (ADHD), a behavioral disorder characterized by inappropriate levels of inattention, hyperactivity and impulsivity, consists of a diverse combination of cognitive deficits, and not all individuals diagnosed with ADHD present all deficits. For instance, many people with ADHD experience difficulties in sustaining attention over time but this impairment is not evident in every individual. Recent studies suggest that ADHD is associated with an impaired ability to anticipate predicable events. Our hypothesis is that the impairment of temporal expectation is related to deficits in sustained attention and therefore the two impairments are expected to co-occur in the same individuals. We utilized a novel approach for studying temporal expectation by examining the inhibition of microsaccades (saccades < 1deg), prior to the onset of predicted stimuli. Methods: 20 participants diagnosed with ADHD and 20 neurotypical participants performed two Continuous Performance Tasks (CPTs) with fixed and random inter-stimulus intervals, while their eye movements were recorded. We estimated "predictive microsaccade inhibition" (PMSI) by comparing microsaccade-rate prior to predictable stimuli (presented in fixed intervals) with microsaccade-rate prior to unpredictable stimuli (presented in random intervals). We divided each group of observers according to their sustained attention performance into two subgroups: 'high' performers and 'low' performers. Results: We found that: (a) Individuals with ADHD showed a smaller PMSI than controls. (b) Within each group, the PMSI was significantly stronger for high- than low-performers. But, when dividing each group according to the Adult ADHD Self-Report scale (ASRS), no such difference was observed. Conclusions: The results show that sustained attention is tightly linked to temporal expectations, as measured by PMSI. The attenuated PMSI in ADHD may impair performance. These results demonstrate that PMSI can be a powerful tool for studying temporal expectations in clinical and neurotypical populations.

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Attention: Neural mechanisms

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.3017 **The interaction of the self and executive control in neuropsychological patients** Jie Sui[1](jie.sui@psy.ox.ac.uk), Glyn Humphreys[1]; [1]Department of Experimental Psychology, University of Oxford

People show biases to self-related information on a range of tasks. In addition, self-related stimuli recruit a ventral network including the ventro-medial prefrontal cortex (vmPFC) and the left posterior superior temporal sulcus (pSTS), contrasting with the more dorsal frontal-parietal network associated with attentional control. This study assessed the interaction between the self and attentional control networks by testing a group of neuropsychological patients and assessing the relations between their brain lesions and any behavioural deficit on processing self vs. others' faces and on executive processing tasks. A factor analyses revealed two underlying factors - one reflecting self processing, and the other associated with executive control in behavioural tasks. Disconnections in the right inferior fronto-occipital fasciculus (IFOF) positively correlated with the self factor while disconnections in the left arcuate, inferior longitudinal fasciculus (SLF2 and SLF3) positively correlated with the attentional control factor. In addition, voxel-based morphometry analyses demonstrated that lesions in the vmPFC were associated with hypo-self bias and lesions in the bilateral dorsal parietal cortex and the left inferior frontal cortex were associated with hyper- self bias and reduced attentional control. The results indicate that the ventral self network and the dorsal frontal-parietal attentional control network play opposite roles in self-bias.

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36.3018 **Feature-selective coding is attenuated during sustained attention** Tom Bullock[1,2](bullock@psych.ucsb.edu), James Elliott[1,2], Priscilla Rosila Mares[3], Lena Nalbandian[1], Barry Giesbrecht[1,2]; [1]Psychological and Brain Sciences, University of California, Santa Barbara, [2]Institute for Collaborative Biotechnologies, University of California, Santa Barbara, [3]MCD Biology, University of California, Santa Cruz

Adaptive, goal-directed behavior requires a cognitive system that supports sustained attention during prolonged tasks. Failures of sustained attention in these tasks can occur and can have very serious consequences in the real world. To investigate the neural mechanisms underpinning these failures, we recorded electroencephalography (EEG) while participants (n=3) engaged in a continuous target detection task. Participants monitored a stream of flickering (30Hz) oriented Gabors (8 possible orientations) for rare long-duration targets (1133ms) presented amongst short-duration (800ms) standards. When a target was detected, participants indicated whether it was oriented left or right of 90°. In three conditions, the stimuli were presented at fixation, distributed across 8 peripheral locations, or fixed at a single peripheral location for the block. Each task consisted of 24 blocks (3.67 min/block). Target detection performance declined from the start of each block (mean=.83, SEM=.05) to the end (mean=.69, SEM=.09). To investigate the neural markers of the performance decline, the blocks were split in half and then an inverted encoding modeling technique was used to estimate orientation- and location-selective tuning functions from the spatially distributed neural activity measured across the scalp (Garcia et al. 2013; Foster et al., 2015). Tuning functions were estimated using power at the steady-state evoked response frequency to the flickering stimuli (SSVEP), in theta (4-7Hz), and in alpha (8-13Hz). The peak amplitude of the SSVEP-based orientation-selective responses was smaller in the second half compared to the first half of the block in the central fixation condition (mean power (SEM)=.12 (.06) vs. .23 (.05)) and in the peripheral-distributed condition (.02 (.01) vs. .10 (.01)). In contrast, location-selective responses in theta, alpha and the SSVEP were unchanged over the block. These data suggest that performance declines during a demanding sustained attention task co-occur with attenuated feature-selective responses in human visual cortex.

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36.3019 **Attentional enhancement of stimulus activation domains in Macque V4.** Yufeng Zhang[1](yufzhang@zju.edu.cn), Hisashi Tanigawa[2], Soo Yang[3], Robert Friedman[4,5], Anna Roe[1,5]; [1]Zhejiang University Interdisciplinary Institute Of Neuroscience and Technology, [2]Center for Transdisciplinary Research, Niigata University, [3]Department of Pathology, Stanford University, [4]Department of Psychology, Vanderbilt University, [5]Behavioral Neuroscience, Oregon Health Sciences University

Visual Area V4 is located in the ventral visual pathway and contains functional domains with different feature preference (Tanigawa et al. 2010). Many electrophysiological papers have shown that the neuronal activity in V4 can be modulated by selective attention. fMRI studies have also shown increase in BOLD activation associated with spatial attention. However little is known about how domain specific activation in V4 is affected by attention. Here we use intrinsic signal optical imaging method to address this question. Using intrinsic signal optical imaging through chronic implanted windows we observed V4 activation in Macaque monkeys performing a covert color-change detection task. In Task1 (Fig. 1a), the monkey was required to detect a subtle color change in one of two gratings (attention in vs. attention out) and to report the direction of color change (from magenta to bluish or to reddish) by making a saccade to one of two targets. In Task2 (Fig. 1b), the monkey was required report the simultaneous change of color and orientation in one grating (attention in vs. passive). In both tasks, when compared to V4 activation during spatially localized change detection (Task1) or when compared to simple fixation of a blank screen (Task2), we found (1) no significant enhancement in domain specific activation magnitude and (2) significant enhancement of domain-domain correlation across stimulus-activated domains (Fig. 2). Further analysis revealed such correlation enhancement during successful trials but not during error trials. In conclusion, utilizing intrinsic signal optical imaging we observed an attention mediated correlation enhancement among the stimulus-activated domains in V4 during change detection task. We propose that directed attention to different locations in space is mediated by magnitude enhancement (Tanigawa et al. Submitted), while attention to feature-related changes is achieved by enhancement of task-related domain-domain correlation in V4.

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36.3020 **Attention alters the orientation tuning for multiple-stimulus displays in human extrastriate visual areas** Nihong Chen[1](nihongch@usc.edu), Bosco Tjan[1,2]; [1]Department of Psychology, University of Southern California, Los Angeles, [2]Neuroscience Graduate Program, University of Southern California, Los Angeles

When multiple stimuli are present in the visual field, competitive interactions between stimuli could be biased by stimulus-driven and attention-driven processes (Desimone and Duncan, 1995; Beck and Kastner, 2009). To study the neural mechanisms underlying multiple-stimulus encoding, we used fMRI and forward encoding model to estimate the orientation-selective responses in human visual cortex to parafoveally presented Gabor arrays. In a heterogeneous array, a center Gabor (eccentricity = 2.5° right of fixation) was surrounded by eight flanking Gabors (0.75° from the center Gabor). The orientation of the flankers was horizontal, while the center Gabor was oriented horizontally, vertically, or ±45°. When attending to the center Gabor, observers could perfectly identify its orientation. In the main experiment, observers performed tasks unrelated to orientation. Using forward encoding model, we decomposed the multivoxel response in each visual area into responses of a hypothetical set of orientation-selective channels (Brouwer and Heeger, 2011; Saproo and Serences 2014). We found that when selective attention was on the entire array, the orientation response to the array was dominated by the orientation of the flankers. This bias increased from V1 to V4. However, when selective attention was directed to the center Gabor, the orientation response began to reflect the orientation of the center Gabor in extrastriate areas: the orientation selectivity for the center Gabor was strongest in V4 while weakest in V1. For a homogeneous array where the flanking and center Gabors had the same orientation, selective attention sharpened orientation tuning in extrastriate areas V2-V4. These findings support the idea that attention resolves the competition among multiple stimuli by counteracting the influences of nearby stimuli, resulting in enhanced information processing at the attended location. This process of biased competition is observable in as early as V2 and appears to be cumulative along the visual-processing hierarchy.

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36.3021 **Engagement of reafferent circuitry facilitates feedforward processing in V1** Ashley Royston[1,2](aroyston@ucdavis.edu), Jaime Napan[1], Kira Anderson[1,2], Steven Luck[1,2], Steven Hillyard[3], George Mangun[1,2,4]; [1]Center for Mind and Brain, University of California, Davis, [2]Department of Psychology, University of California, Davis, [3]Department of Neurosciences, University of California, San Diego, [4]Department of Neurology, University of California, Davis

Selective attention—the selection of task-relevant information and the suppression of distracting information—is crucial for flexible and yet efficient behavior. Classic studies of human cognition have probed visual selective attention using briefly presented stimuli, yielding reliable attentional modulations of visual evoked activity. However, such designs fail to capture the complexity of continuously visible real-world visual scenes, thereby leaving open questions concerning the application of these findings to more natural viewing scenarios, and perhaps failing to reveal key mechanisms. For example, although electrophysiological studies in nonhuman primates and fMRI studies in humans have reported replicable effects of spatial selective attention in striate cortex and midbrain structures, ERP studies in humans have yielded inconsistent results. We hypothesize that in natural vision, the presence of continuous inputs may trigger an attention-related engagement of reafferent circuitry in V1 such that subsequent feedforward inputs benefit from enhanced attentional modulation at this early cortical locus. To test this, we conducted three ERP experiments in which human subjects covertly attended to one hemifield in order to detect occasional, briefly presented gratings on a gray background (classic design) or occasional decrements of a continuously present, static or drifting, background grating (static and dynamic designs, respectively). To eliminate concerns that blinks or eye movement may account for the observed effect, we collected eye tracking data concurrently with EEG and excluded all periods of non-optimal participant fixation from ERP analyses. The results we obtained support our hypothesis, showing a significant modulation of ERPs generated in V1 (i.e., the C1 component of the visual ERP) in the ongoing stimulus condition compared with the classic condition. Our findings suggest that attentional engagement of reafferent circuitry enhances processing of feedforward inputs in human V1 during selective attention to ongoing stimulation, which is more similar to the conditions faced in natural vision.

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36.3022 **Attentional gain modulation relies on local feature-tuned normalization.** Ilona Bloem[1,2](im.bloem89@gmail.com), Sam Ling[1,2,3]; [1]Department of Psychological and Brain Sciences, Boston University, Boston, [2]Center for Computational Neuroscience and Neural Technology, Boston University, Boston, [3]Donders Institute, Radboud Universiteit, Nijmegen, the Netherlands

Attentional feedback has been shown to evoke increases in the gain of early visuocortical responses, but its effects are rather heterogeneous, even within a visual area. What neural computations give rise to these gain changes? Here, we used fMRI to investigate the hypothesis that gain increases with attention rely on normalization. Specifically, we examined whether visuocortical responses that exhibit stronger weighted feature-tuned normalization would also exhibit larger attentional benefits. To do so, we measured the local, voxel-wise magnitude of both orientation-tuned normalization and attentional modulation within early visual cortex. We assessed normalization strength by presenting participants with stimuli composed of two oriented gratings, which were combined in either a collinear or orthogonal configuration. Collinear stimuli evoked weaker mean BOLD responses than orthogonal stimuli, indicating substantial tuned normalization in early visual areas. Furthermore, the magnitude of local normalization strength varied substantially between voxels within a visual area, indicating heterogeneity across a population. We next explored how local normalization strength correlates to the magnitude of attentional modulation. Attentional modulation was measured in the same participants by presenting oriented stimuli, which participants either covertly attended towards (performing a fine orientation discrimination task), or attended away from (performing a demanding task at fixation). We found an overall increase in BOLD response when attention was directed towards a stimulus. Voxel-wise analyses illustrated substantial variability in the amount with which attention boosted stimulus-evoked responses. Leveraging the population-wide heterogeneity in both measures, we discovered a strong association between normalization strength and the strength of attentional modulation. Taken together, our results reveal a link between attentional gain and normalization, suggesting that these two measures potentially share a common mechanism, allowing attention to improve perceptual discriminability by modulating local circuitry in early visual cortex.

36.3023 **Multiple Objects of Attentional Selection in Human Visual Cortex** Xilin Zhang[1](XILIN.ZHANG@NIH.GOV), Nicole Mlynaryk[1], Shruti Japee[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, Bethesda, Maryland, USA

How many different objects we can select at once remains unclear. Here, we used functional magnetic resonance imaging to address this question as human subjects performed object-based attention tasks that required simultaneous attention to two objects that differed in either their features (Experiment 1) or locations (Experiment 2). In Experiment 1, subjects viewed stimuli consisting of a face transparently superimposed on a house. They either attended to the motion direction in a moving face with a static house (MFSH), a static face with a moving house (SFMH), and in a condition with a moving face with a moving house (MFMH), or attended to the static position in the MFSH and SFMH conditions, and in a condition with a static face with a static house (SFSH). When subjects attended to the motion direction, no significant difference in fMRI signal was found between MFMH and MFSH conditions in the fusiform face area (FFA) or between MFMH and SFMH conditions in the parahippocampal place area (PPA). When subjects attended to the static position, no significant difference in fMRI signal was found between SFSH and SFMH conditions in FFA, or between SFSH and MFSH conditions in PPA. In Experiment 2, subjects were randomly cued to attend to one location in a circular arc (the single cue condition) or to two locations in two different circular arcs (the double cue condition). These two different conditions showed no significant object-based attentional effect, i.e. activation was greater in regions representing uncued locations on the attended circular arc than regions representing equidistant locations on the unattended circular arcs, in human V1. These results provide direct evidence that object-based attention can select at least two objects that differ in either their features or locations simultaneously.

36.3024 **Task-Irrelevant Semantic Relationships of Real-World Objects Bias Visual Attention** Joseph Nah[1](nah@gwu.edu), George Malcolm[2], Summer Sheremata[3], Sarah Shomstein[1]; [1]George Washington University, [2]University of East Anglia, [3]Florida Atlantic University

Recent research strongly suggests that semantic information influences attentional allocation (de Groot, Huettig, & Olivers, 2015; Moores, Laiti, & Chelazzi, 2003). However, most experiments showing semantic contri-

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bution have rendered semantic information central (relevant) to the task. Therefore, whether semantic information automatically (as a default) influences attentional allocation remains an open question. Recent behavioral evidence from our lab showed that when participants are presented with three objects, two of which are semantically related, attention is biased towards semantically related objects (Malcolm & Shomstein, 2014). Here, we employed fMRI to elucidate the underlying neural mechanism responsible for this automatic semantic biasing of attention. We hypothesized that if semantic information biases spatial attentional selection, then in addition to semantic-based modulation of early visual cortex (V1-V3) we should observe semantic-based modulation of spatial representations in inferior-parietal sulcus (IPS0-2). Additionally, if semantic bias is distributed broadly across the network then we should observe semantic based modulation in object-selective cortex (LOC). Participants viewed three objects, with one just above the central fixation and one in each periphery, below the midline. One of the peripheral objects was always semantically related to the central object. After the objects were presented, a target and two distractors were superimposed on top of each object. Critically, the target appeared on all three objects equally, rendering semantic relatedness task-irrelevant. Responses to semantically related and semantically non-related objects were compared in each ROI. We observed higher responses to semantically related objects throughout the early visual cortex as well as LOC. Interestingly, responses in IPS were only weakly modulated by semantic relatedness. Non-univariate analyses corroborated the observed pattern of results. Together, the results strongly suggest that task-irrelevant semantic information automatically constrains attentional allocation by directly acting on object representations in LOC and V1-V3.

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36.3025 **Uncertainty Modulates Object Representations in LOC and Spatial Representations in IPS** Andrew Collegio[1](ajcollegio@email.gwu.edu), Joseph Nah[1], Summer Sheremata[2], Dwight Kravitz[1], Sarah Shomstein[1]; [1]Department of Psychology, The George Washington University, [2]Department of Psychology, Florida Atlantic University

According to the uncertainty hypothesis proposed in the object-based attention literature, object representations influence attentional allocation only under conditions of high spatial uncertainty. When two task-irrelevant objects appear on the screen and participants are asked to detect targets that are presented on those objects, behavior is influenced by objects only if the location of the upcoming target is unpredictable. These behavioral observations make a counterintuitive and provocative prediction regarding the strength of object representations in object selective cortex. Evidence from fMRI literature has demonstrated that the lateral occipital complex (LOC) is sensitive to object representations, while the intraparietal sulcus (IPS) is sensitive to spatial locations. We hypothesize that if spatial uncertainty has influence on object representations, then decoding of object identity in LOC should increase when target location is unpredictable, and decrease when target location is predictable. Alternatively, decoding of spatial representations in IPS should decrease when target location is unpredictable, and increase when target location is predictable. While in an fMRI scanner, participants were presented with two task-irrelevant objects (left and right of fixation). Following a delay, a Gabor patch appeared on one of the objects and participants were asked to indicate its orientation (45°left/right). Three conditions were used: (1) Uncertain: target location was unpredictable; (2) Certain Left: the target appeared 75% on the left object; and (3) Certain Right: the target appeared 75% on the right object. In the Uncertain condition, we observe similar or better LOC decoding of object identity in the contralateral hemifield compared against either Certain condition. Likewise, decoding of spatial information in the contralateral hemifield decreases in IPS in the Uncertain condition. Combined, these findings support the hypothesis that attentional uncertainty triggers a change in neural representations of objects.

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36.3026 **The unique representational similarity structure of face morphs predicts performance in an independent visual search task** Jeongmi Lee[1](jmslee@ucdavis.edu), Joy Geng[1,2]; [1]Center for Mind and Brain, University of California, Davis, [2]Psychology, University of California, Davis

The representation of task-related information determines the speed of attentional selection and distractor suppression. However, it remains unclear how individually-unique neural representation of stimulus similarity affects attentional processes. We investigated this problem by examining the relationship between brain regions that encode unique categorical representations of face identity and performance in an independent visual search task. Functional magnetic resonance imaging (fMRI) data were acquired during a task in which face morphs between two famous face identities were classified as one or the other person. In addition, a house or a scrambled face image was sometimes presented and required the third "non-face" response. Representational similarity analysis (RSA) was used with a whole-brain searchlight procedure to identify regions with patterns of activation that correlated with identity classification (using the Spearman rank correlation coefficient). The results showed that patterns of activation in the prefrontal areas as well as in the face selective areas in the ventral temporal cortex were highly consistent with the classification of face identity, reflecting individually-unique relationships between behavioral and neural representational structures. Interestingly, performance in an independent visual search task in which one of the face identities served as the target and the various face morphs appeared as distractors was predicted by the behavioral and neural patterns during the classification task: reaction times to select the target increased as the classification similarity between the target and the distractor morph increased. Particularly, the neural representational structure in right DLPFC predicted individual differences as well as commonalities of the visual search performance. These results suggest that task-relevant internal representations reflect the categorical structure of target and distractor stimuli that is encoded in prefrontal areas as well as in stimulus-specific perceptual areas, and the individually-unique similarity structure of task stimuli can predict competition for attentional selection in an independent search task.

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36.3027 **Visual attention modulates feature-specific representations in human frontoparietal cortex.** Edward Ester[1](eester@ucsd.edu), David Sutterer[2], Edward Awh[2], John Serences[3]; [1]Department of Psychology, University of California, San Diego, [2]Department of Psychololgy and Institute for Mind and Biology, University of Chicago, [3]Department of Psychology and Neurosciences Graduate Training Program, University of California, San Diego

Control over visual selection has long been framed in terms of a dichotomy between "source" and "site", with frontoparietal cortical areas serving as the source of control signals and posterior sensory regions serving as the site for visual processing. This distinction is motivated in part by studies suggesting that frontoparietal cortical areas encode abstract or categorical representations of task goals while posterior sensory areas encode detailed representations of stimuli. Here, we present evidence that challenges this distinction. We used fMRI, a roving searchlight analysis, and an inverted encoding model to examine representations of an elementary feature property (orientation) across the entire human cortical sheet while participants attended either the orientation or luminance of a peripheral grating. We observed robust, continuous representations of orientation in many sensory and frontoparietal cortical areas, including medial and lateral visual cortex, medial and lateral parietal cortex, the superior precentral sulcus, lateral prefrontal cortex, and posterior cingulate cortex. Additionally, we found that attention modulated the amplitudes of orientation-selective representations in several frontoparietal regions, including bilateral posterior parietal cortex and the superior precentral sulcus. Collectively, these findings challenge models that posit a dissociation between the source and site of attentional modulations by demonstrating that feature-based attention enhances the strength of continuous feature-selective representations across the visual processing hierarchy.

36.3028 **Local Immediate Versus Long-Range Delayed Impact Of rTMS On The Visual Attention Network** Lorella Battelli[1,2](lorella.battelli@iit.it), Ela Plow[3], Emily Grossman[4]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Fondazione Istituto Italiano di Tecnologia, [2]Berenson-Allen Center for Noninvasive Brain Stimulation, Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, [3]Department of Biomedical Engineering and Department of Physical Medicine and Rehabilitation, Cleveland Clinic, [4]Department of Cognitive Sciences, Center for Cognitive Neuroscience, University of California, Irvine

Long-lasting, maladaptive interhemispheric imbalance is hypothesized to be the basis of sustained attention deficits in chronic phase of stroke, which are readily identified during bilateral visual tracking (Battelli et al., 2009). In a test of the causal role of interhemispheric imbalance in chronic stroke, Agosta et al. (2014) improved visual tracking in chronic right parietal patients with 1Hz offline inhibitory rTMS to the healthy left parietal cortex, re-establishing the interhemispheric balance. In that study, behavioral improvements peaked 30 minutes following stimulation. In this study, we measure

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the timecourse of cortical reorganization following rTMS over left parietal cortex in healthy individuals engaged in visual tracking. Method. Subjects engaged in a visual tracking task following offline, inhibitory rTMS or sham (conducted on 2 separate days in a counter-balanced order). fMRI data collection was initiated within four minutes from completion of rTMS/sham, with subjects engaged in tracking during four 12 minute scans. We computed functional connectivity (FC) between three nodes of the attention network engaged by visual tracking: the intraparietal sulcus (IPS), frontal eye fields (FEF) and human MT+ (hMT+). Results. rTMS immediately and significantly decreased FC between the stimulation site (left IPS) and all other regions, and FC recovered to normal levels within 30 minutes. rTMS caused increases in FC between left and right FEF at approximately 36 min following stimulation, and between sites in the unstimulated hemisphere approximately 48 min after stimulation. Conclusion. rTMS has immediate impact on functional connectivity directly under the stimulation site, and substantially delayed effects remotely. These findings are consistent with rTMS over left IPS inducing interhemispheric imbalances throughout the healthy brain during visual tracking (Plow et al., 2014) and delayed changes in the FEF following theta burst stimulation during a saccade task (Hubl, 2006).

36.3029 **The Contribution of the Left Posterior Parietal Cortex to Proactive and Reactive Cognitive Control** Brandon Ashinoff[1](brandon.ashinoff@gmail.com), Joy Geng[2], Foyzul Rahman[1], Caitlin Carruthers[1], Diana Maler[1], Carmel Mevorach[1]; [1]School of Psychology, University of Birmingham, UK, [2]Department of Psychology, University of California, Davis

Braver (2012) recently proposed the dual mechanisms of cognitive control (DMC) framework, which postulates that the brain utilises two distinct modes of cognitive control. In Proactive control, selection and suppression relies on a preparatory mechanism (before stimulus presentation) while in reactive control, selection and suppression takes place following stimulus presentation. However, the critical brain mechanisms underlying these modes of control as well as the potential interplay between them are still poorly understood. Previously we have shown that the left intraparietal sulcus (IPS) is critically involved in suppression of salient distractors before their presentation (alluding to its involvement in proactive control; Mevorach et al, 2008). In contrast, the left temporoparietal junction (TPJ) has also been shown to activate (using fMRI) when suppression of salience is called upon (Geng and Vossel, 2013), but this may be when reactive control is needed following stimulus presentation. In the present study we used brain stimulation (TMS) to establish a causal link between the left TPJ and reactive control mode. In order to investigate the interplay between proactive and reactive control we also asked whether interfering with proactive control (in the left IPS) will result with increased utilization of reactive control. We applied offline TMS (1 Hz, at 60% intensity) over the left IPS, the left TPJ, and a control region (Vertex) before participants performed a visual search task for a low contrast target in the presence of either a high or low contrast non-target (which has been shown to rely on reactive control (DiQuattro and Geng, 2011). Our results suggest a critical role for the left TPJ in this task. Furthermore, we found no impact on performance following left IPS stimulation. We conclude that left TPJ and left IPS are differentially involved in reactive and proactive control and that these modes of control act independently.

36.3030 **A unique Go/No-go task reveals specific inhibition-related activation in the right IPS** Tamar Kolodny[1](tamar.kolodny@gmail.com), Pnina Stern[2], Maya Ankaoua[3], Natalie Kataev[4], Carmel Mevorach[5], Lilach Shalev[2,3]; [1]Department of Cognitive Sciences, the Hebrew University of Jerusalem, [2]Constantiner School of Education, Tel Aviv University, [3]Sagol School of Neuroscience, Tel Aviv University, [4]School of Psychology, Tel Aviv University, [5]School of Psychology, University of Birmingham, UK

Introduction: Response inhibition - the ability to suppress inadequate but pre-potent response tendencies - is a cognitive-motor effortful process, in the realm of cognitive control. Interestingly, impaired response inhibition has been suggested as a key component in disorders such as ADHD. However, the brain mechanisms typically reported for response inhibition are extensive and provide poor markers for investigating atypicalities. Methods: We used rapid event-related functional magnetic resonance imaging (fMRI) to investigate the neural mechanisms underlying response inhibition in healthy controls. Participants performed a novel Go/No-go task that minimizes intervening factors such as perceptual complexity and working memory, while emphasizing attentional components. Manipulation of the frequency of targets, from 25% to 75%, enabled us to create a contrast of No-go trials at different frequencies. This contrast is expected to isolate inhibition-related activity while eliminating the involvement of motor, perceptual and working memory components. Results and discussion: Unlike previous reports, which in most cases contrasted No-go trials with Go trials and yielded activations in widespread fronto-parietal networks, our unique design allowed us to isolate a distinct cluster of activation in the right intraparietal sulcus (rIPS). Our findings suggest that the rIPS may serve as a potential neuroanatomical marker for response inhibition. In future studies we will utilize this marker, comparing the neural response in participants with and without ADHD, and investigating the relation of this focal activity to behavioural measures and symptomatology of attention deficits.

36.3031 **Dissociation of spatial and feature-based attention in visual working memory: a TMS study** Anna Heuer[1,2](anna.heuer@uni-marburg.de), Anna Schubö[1,2], John Crawford[1,3,4,5]; [1]International Research Training Group, IRTG 1901, "The Brain in Action", [2]Experimental and Biological Psychology, Philipps-University Marburg, Marburg, Germany, [3]Centre for Vision Research, York University, Toronto, Ontario, Canada, [4]Canadian Action and Perception Network, York University, Toronto, Ontario, Canada, [5]Departments of Psychology, Biology, and Kinesiology and Health Sciences, York University, Toronto, Ontario, Canada

Attention can be deployed to representations in visual working memory (VWM), ensuring that only the most relevant information is maintained. We investigated whether the attentional selection of VWM representations can operate on features just as well as on spatial information, and we used transcranial magnetic stimulation (TMS) to test whether these attentional mechanisms can be dissociated based on the site of cortical stimulation. During the retention interval of a VWM task, a so-called retrocue was presented, which was either uninformative or indicated the item that would be tested at the end of the trial. The test item was cued by its location (spatial attention) or by its shape (feature-based attention). During cue presentation, TMS was applied to the supramarginal gyrus (SMG), which has been implicated in spatial attention, or to the lateral occipital cortex (LO), which is involved in representing object shape. We observed improved memory for objects cued by location and shape, confirming that both spatial as well as featural information can be used for selecting representations in VWM. Importantly, stimulation of SMG selectively facilitated spatial attention and stimulation of LO selectively facilitated feature-based attention. These results show that spatial and feature-based attentional mechanisms in VWM recruit distinct cortical regions. The same regions have been shown to be involved in attention to external events, indicating that attention in the mnemonic and in the perceptual domain are similarly implemented at the neural level. In general, these findings extend our understanding of how attentional mechanisms operating on different types of information optimize the use of the highly limited VWM system, allowing for an efficient and flexible updating of its contents.

36.3032 **Effects of neural ensemble size and composition on the decoding of attention in primate lateral prefrontal cortex** Lyndon Duong[1,2,3](lduong4@uwo.ca), Matthew Leavitt[4], Sebastien Tremblay[5], Adam Sachs[6], Julio Martinez-Trujillo[1,2,3]; [1]Department of Physiology and Pharmacology, Western University, London, ON N6A 3K7 Canada, [2]Robarts Research Institute, Western University, London, ON N6A 3K7 Canada, [3]Brain and Mind Institute, Western University, London, ON N6A 3K7 Canada, [4]Department of Physiology, McGill University, Montreal, QC H3A 2B4 Canada, [5]Montreal Neurological Institute, McGill University, Montreal, QC H3A 2B4 Canada, [6]The Ottawa Hospital, Ottawa, ON K1Y 4E9, Canada

The allocation of attention can be decoded from the activity of lateral prefrontal cortex neuronal ensembles (Tremblay et al., 2015). One issue that remains unclear is the impact of a neural population's size and composition on decoding of attention. To investigate this, we recorded the responses of neurons in lateral prefrontal cortex of two macaques using microelectrode arrays while they performed a visuospatial attention task. During the task, the animals had to direct attention to a cued target stimulus positioned in one of the four visual quadrants while ignoring 3 identical distractors positioned in the remaining quadrants. We systematically changed the size and composition of the neuronal ensembles, as well as the pattern of noise correlations, and evaluated their information content using a linear decoder. First, we found that the location of visuospatial attention was reliably decoded from ensembles of approximately 50 units (mean accuracy = 76%, $p < 0.05$, Permutation test). We progressively increased the number of neurons in an ensemble from 1 to 50 units and assessed decoding performance using two methods; first, we built subnetworks of most informative neurons, and second, we built subnet-

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works that maximized information of the ensemble. We found that the decoding performance of the most informative subnetworks was higher than those composed of the most informative units. Interestingly, the most informative subnetworks were not necessarily comprised of most informative units, including in many cases non-selective units (Kruskal-Wallis test P>0.05). Finally, removing noise correlations increased the decoding performance of ensembles of most informative units (6%, Signed rank P< 0.01), whereas removing correlations in most informative subnetworks of equivalent size had no effect on performance (Signed rank P>0.05). These results indicate a complex effect of ensemble size and composition on the coding of attention in lateral prefrontal cortex neuronal ensembles.

36.3033 Decoding visual salience and behavioral relevance from neuronal oscillations in the superior colliculus

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Saliency map theory postulates that visual input is transformed into a topographic representation of visual conspicuity, which interacts with goal-related signals on a behavioral priority map for the control of attention/gaze. We have shown evidence that the superior colliculus (SC) is suited for the role of a saliency and priority mechanism, compartmentalized within its visual (SCs) and visuomotor (SCi) layers, respectively. Here, we examined how visual-salience and behavioral-relevance are coded in SC neuronal oscillations, while monkeys were presented with salient stimuli that were either goal-relevant or -irrelevant. Stimuli consisted of either a single item, or an array of items with a salient oddball (defined by color-orientation difference), which appeared in or opposite the receptive field (RF). In the first experiment, stimuli were goal-irrelevant because gaze was contingent upon a separate stimulus that always stepped orthogonal to the RF. We recorded local field potentials (LFP) using single electrodes and examined LFP power across conditions. Presenting the item or oddball in the RF caused a transient increase in LFP power across a broad (~15-90Hz), and separable narrow (5-12Hz), band that lasted ~200ms. This transient response was not modulated by saliency, and was similar in SCs and SCi. This was followed by prolonged (≥500ms) suppression at narrow beta (15-30 Hz) and theta/alpha (5-12 Hz) frequencies. The beta suppression was evident even when there was no stimulus in the RF, and was similar for the oddball and item. In contrast, the alpha/theta suppression was more pronounced for the oddball relative to the item. This frequency-specific signal was mostly restricted to the SCs. In a second experiment, where the stimulus was made goal-relevant, we observed a sustained increase in beta and low-gamma frequencies. These results may provide insight into how signals related to visual-salience and behavioral-relevance combine to establish a distributed priority map.

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36.3034 Using Temporally Aligned Event-Related Potentials to Investigate Attention Shifts Before and During Eye Movements

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Event-related potentials (ERPs) are usually used to study visual attention in the absence of eye-movements. For example, in visual search, about 200 ms after stimulus onset, more negative potentials are observed at posterior electrodes contra- than ipsilateral to a searched-for stimulus (N2pc or PCN). It is usually assumed that such laterality effects, as the N2pc, indicate attentional selection of the target stimulus before saccade execution, although this has not been investigated without constraining saccade parameters in some way either during the task, or later in the analysis. Here, we present an approach to investigate pre-saccadic attention shifts in an unconstrained way. Participants searched for a color-defined target in single-target and two-targets blocks while ERPs and eye-movements were recorded. Single-target blocks required a single saccade; two-targets blocks required either a single saccade to one of the targets or two successive saccades to both targets. In two-targets blocks, targets could appear on the same or on opposite sides of the vertical midline. If targets captured attention and pre-saccadic attention shifts to saccade target locations were necessary for saccade execution, we would expect enhanced attentional competition between (1) two targets compared to single targets; (2) two opposite-sides targets compared to two same-side targets; and (3) two saccades rather than one saccade conditions. More attentional competition was expected to delay saccade latency and to weaken and delay pre-saccadic laterality effects in ERPs. By means of temporal alignment we time-locked ERPs simultaneously to stimulus onsets, saccade onsets, and saccade offsets. Predictions (1) and (2) were partly and fully confirmed, respectively, but no evidence was found for (3). We explain the implications of our results for the role of attention during saccade preparation, and we point out how our method of temporally aligning ERPs compares to ICA-based EEG artifact correction procedures and to psychophysical dual-task approaches.

36.3035 A Standardized Methodology for Co-Registering Eye-Tracking and EEG Data

Joshua Zosky[1](joshua.e.zosky@gmail.com), Carly Molloy[1], Mark Mills[1], Arthur Maerlender[1]; [1]Psychology, University of Nebraska - Lincoln

A popular new field in vision and neuroimaging is the co-registration of eye-tracking information with EEG recordings. Accomplishing this previously was a complicated and non-standardized procedure. This poster presents a free, open-source, operating system independent framework for conducting co-registration experiments. OpenSesame was used for experimental control and stimulus presentation, along with the PyGaze plugin and PyNetstation plugin. PyGaze is for control of multiple eye-tracking systems under uniform conditions, in this scenario it was tested with a Tobii TX 300 eye tracking system. PyNetstation was used for control of Net Station EEG recording software and event markers, while most EEG systems can receive stimulus signals through a simple serial-port/parallel-port command within OpenSesame. A facial stroop task used to test participants for attention was used to determine the efficacy of equipment for creating a set up in which one could conduct co-registration analyses. The task presented participants with a face showing happy or sad emotions, and also showed the word "happy" or "sad" somewhere onscreen. If the face was presented centrally onscreen, a word was overlaid on the forehead. If the face was on the left or right side of the screen, then the word was on the opposite side of the screen. Participants were instructed to press a button to indicate when the face showed happy emotions or to press a different button when the face showed sad emotions. Visual fixations were determined in real-time within the experiment, and their onset and location were flagged in the EEG data. Data were analyzed to event-related potentials (ERP) and eye-fixation related potentials (EFRP) to determine the presence of an N170 component, commonly observed as a "face specific" component. Comparison of ERP and EFRP methods indicated the latter more reliably detected the N170 component, validating the utility of the proposed framework.

36.3036 Auditory alerting enhances visual attentional processing: Evidence from computational modeling and event-related lateralizations

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Attentional performance depends on an individual's level of alertness, which refers to a state of responsiveness that enables the organisms to process stimuli faster and more efficiently (Posner & Petersen, 1990). A phasic, short-lived increase of alertness can be induced by an external warning cue signaling the imminent occurrence of a stimulus. Alertness states are assumed to be controlled by a distributed neuronal network involving frontal and parietal lobes, thalamic and brain stem areas (Sturm & Wilms, 2001). Which aspects of attentional processing are affected by phasic alertness, and the neural mechanisms underlying the effects, however, are only poorly investigated. In this study, we measured performance and EEG of 20 young participants in a partial letter report task with an auditory alerting manipulation. Report accuracy was modeled based on the computational "Theory of Visual Attention" (Bundesen, 1990), and we estimated several, independent parameters of visual attention performance: Sensory effectiveness (= the total available processing capacity), spatial bias (relative weighting of right-vs. left-hemifield stimuli), and distractibility (relative weighting of target and distracter stimuli). We computed visual event-related lateralizations (ERLs), which reflect contra-vs.-ipsilateral differences in sensory processing of laterally presented stimuli, and mark amplification of stimulus-related processing by selective attention (Hillyard et al., 1998). We found that phasic alerting increased sensory effectiveness significantly, which was accompanied by an increased lateralized N1 in response to unilaterally presented stimuli. By contrast, spatial weighting and distractibility, and the parameters' ERL correlates (Wiegand et al., in prep.), were not affected by the phasic alerting manipulation. The results indicate that in young, healthy participants, phasic

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alerting increases the total attentional processing capacity that is allocated to a stimulus, but not how capacity is divided between multiple stimuli in the visual field depending on their spatial position or task-relevance.

Acknowledgement: Danish Council for Independent Research

36.3037 **Visual Tasks Lead to Unique Sequences of Cyclic Attentional Signals** John Tsotsos[1,3](tsotsos@cse.yorku.ca), Thilo Womelsdorf[2,3]; [1]Dept. of Electrical Engineering and Computer Science, York University, [2]Dept. of Biology, York University, [3]Centre for Vision Research, York University

The enormous breadth of human visual tasks highlights the question of how the visual cortex achieves this incredible generality. Recently, models of vision and visual attention (e.g., Tsotsos 2011, Beuth & Hamker 2015) have incorporated specific solutions toward such generality resulting in the insight that different visual tasks require unique patterns of neural activations to occur with specific timings in order to provide unified response. For example, sub-tasks such as task-set specific priming of visual features, disengaging from a previous attentional focus, selection of a next focus, matching focus to task, eye movements, storing extracted information into working memory, recognition of task completion (or failure), and resetting for the next task need to be set up, initiated, monitored and terminated with precise timing and coordination. Each computation takes time, each transfer of information between representations takes time, network transmission speeds and neural distance travelled vary, motor actions take time and so on. It is a major question to determine how segregated computational operations are temporally coordinated. Appeals to attentional executive processes and (de-)centralized control operations have appeared in the literature, but the desired generality has remained elusive in concept as well as possible neurobiological realization. Here, we outline in the context of the Selective Tuning model (Tsotsos et al. 1995; Tsotsos 2011), how attentional control signals and their timing depend on the specific task being performed. We outline how tasks define sequences of computations with unique content and duration. We predict that these computational sequences give rise to periodic, oscillatory activity that is measured across visual and fronto-parietal networks implementing attentional control of vision. We show how the computational constraints underlying visual tasks suggest a temporally precise unfolding of neural activation that is likely evident in brief periods of oscillatory activity measured across visual and attention networks of the brain.

36.3038 **Neural circuit activity manipulation in the striatum influences decision process for visual detection in mice** Lupeng Wang[1](lupeng.wang@nih.gov), Richard Krauzlis[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health

Visual detection is a process that not only requires sensory processing, but also includes decision mechanisms that map sensory events onto motor actions and perceptual states. With that view in mind, we hypothesized that manipulating the activity in neural circuits involved in the decision process might change both detection criteria and sensitivity. To test this idea, we used optogenetics to artificially activate specific neuronal populations in the striatum, a brain region best known for its role in reinforcement learning and action selection, in mice performing a visual detection task. The visual stimuli consisted of two vertically oriented Gabor gratings superimposed on a pink noise background. Head-fixed mice walked on a Styrofoam wheel, and the drifting rate of visual gratings depended on walking speed. During individual trials, after mice traveled a randomized distance, one of the two gratings changed its orientation. The task of the mice was to lick the spout if an orientation change happened, and to otherwise withhold from licking. We used transgenic mice and viral systems to target the direct and indirect pathway medium spiny neurons (MSNs) in the striatum. During optogenetic stimulation experiments, a brief light pulse was delivered to the striatum through an implanted optic fiber at the onset of the orientation change in a randomized subset of trials. Our preliminary data show that: 1) activating indirect MSNs caused a large reduction (~0.5) in sensitivity for visual stimuli presented contralateral to the stimulation side, and reductions (~0.4) in response criterion for both ipsilateral and contralateral stimuli; 2) activating direct MSNs caused a larger reduction (~0.7) of response criterion for the contralateral side, and a similar but small reduction (~0.3) of sensitivity for both sides. These results suggest that striatal direct and indirect pathways play differential roles in the decision mechanisms underlying visual detection.

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36.3039 **Occasional awareness of a tree with no forest: Deriving PPC perceptual role from a simultanagnosia case study** Marina Pavlovskaya[1,2](marinap@netvision.net.il), Yoram Bonneh[3], Shaul Hochstein[4], Nachum Soroker[1,2]; [1]Loewenstein Rehabilitation Hospital, Raanana, Israel, [2]Sackler Faculty of Medicine, Tel-Aviv University, Tel-Aviv Israel, [3]Department of Optometry, Bar-Ilan University, Israel, [4]ELSC Safra Center for Brain Research, Neurobiology Department, Life Sciences Institute, Hebrew University, Jerusalem, Israel

Background: Patients with Balint syndrome following bilateral parietal damage are typically described as being unable to perceive multiple objects simultaneously, preventing them from understanding the visual scene despite correct identification of individual visual objects (simultanagnosia). We report observations with DP, a patient with a rare stroke-related pattern of damage affecting the right and left posterior parietal cortex (PPC), shedding new light on simultanagnosia and the role of PPC in conscious perception. Results: (1) DP experienced fading or disappearance of salient objects or object parts, such as face parts, or even a single patch on a blank screen, reporting alternating onsets and offsets every few seconds. He also reported anti-correlated disappearance of competing objects such as orthogonal bars. (2) DP had a surprisingly intact ability to identify very small digits or color patches, when centrally presented, but this was dramatically degraded when spatially crowded with flanking patterns. (3) He had a severe deficit in reporting relative positions of objects or pointing to marked locations on a touch screen. (4) Nevertheless, both in Gestalt grouping and in size-averaging tasks, DP seemed to be grouping arrays, some of which were invisible to him. Conclusions: These findings, and especially the dynamic alternating perception and fading of isolated patches or large fragments of the visual scene, are not consistent with common single-object perception descriptions of this syndrome, and theories stressing a global/focal imbalance. We propose that PPC serves as a short-term data-holding mechanism for spatially coded information by which contextual factors modulate perception-declaration and perception-action links. Bilateral PPC damage causes simultanagnosia due to failed maintenance of visual information in spatio-temporal working memory.

Acknowledgement: Israel Science Foundation

Color and Light: Cognition

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Banyan Breezeway

36.3040 **Color language reflects usefulness of color** Bevil Conway[1,2](bconway@wellesley.edu), Julian Jara-Ettinger[2], Kyle Mahowald[2], Steven Piantadosi[3], Leon Bergen[2], Richard Futrell[2], Edward Gibson[2]; [1]Neuroscience Program, Wellesley College, [2]Brain and Cognitive Sciences, MIT, [3]Brain and Cognitive Sciences, Rochester University

Languages vary in their number of color terms. Why? The two dominant theories (universalist hypothesis and linguistic-relativity hypothesis), do not account for empirical evidence. Here we test an alternative, the "efficient-communication hypothesis", which postulates that all people with trichromatic vision have similar color perception, but vary in color language depending on the usefulness of color to behavior. We test this hypothesis in three groups: the Tsimane', a hunter-gatherer isolate in the Bolivian Amazon; Spanish speakers from San Borja, Bolivia; and English-speaking students in Boston. Compared to Spanish and English speakers, the Tsimane' interact less with industrialized objects, which are often only distinguishable using color. We hypothesized that color is less useful for the Tsimane'. We make three observations. First, when asked to label colored chips or objects, each population used about the same number of terms. But each Tsimane' individual was idiosyncratic in the color terms they used, unlike English and Spanish speakers, who were largely consistent. Second, the Tsimane' were less likely than English speakers to use color terms spontaneously in a contrastive object-labeling task. When confronted with objects distinguished only by color, English speakers spontaneously attached color labels to identify the objects but the Tsimane' did not. Third, the Tsimane' took longer than English speakers to label chip colors; in control experiments the Tsimane' were comparable to English speakers at labeling objects, showing that the Tsimane' understood the experimental task. The number of color terms used by Tsimane' individuals and the efficiency of color-term usage increased with increased exposure to Spanish, suggesting a mechanism for cultural transmission. Together, these results suggest that the variability

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in the number of color terms across cultures is not caused by language itself, nor an innate set of universal color categories, but rather variability in the relative cost-benefit associated with expanding color vocabulary.

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36.3041 How does color naming interact with color memory?

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Humans break the color wheel into smaller segments, each labeled by a color name. Some individuals employ more names to segment the color wheel and some, less sophisticated with color names, use fewer names. Here we measured the relationship between the number of color names and color matching performance across individuals. 100 hues (equal saturation and brightness) were evenly sampled from the color wheel and presented to the subjects (n=10, Persian speakers, ages 20-30) in two conditions. In "perceptual matching" condition, a test-patch and a reference-patch were displayed simultaneously. The subjects adjusted the color of the test-patch to match it to the reference-patch. The "memory based matching" condition was the same except that the reference-patch was displayed for 10s, then the test-patch was presented following a 10s interval. In a separate session, the same subjects were presented with the 100 tested hues and asked to type their names (Persian). The number of unique color names (for describing the 100 tested hues) and the average error for color matching (the difference between observed and matched hues) were correlated across subjects for the two conditions. The more color names the subjects possessed the less color matching error they had for memory based matching (r= -0.68, p< 0 .05). This correlation was not significant for perceptual matching (r= -0.02, p=0 .25). Next, we collapsed the data from all subjects and defined "name-density" (ND); the number of color names in Persian for 10-hues-wide bins of the color wheel centered at each hue. The ND of each hue was negatively correlated with its color matching error for memory based matching (r=-0.27, p< 0.05) and not for perceptual matching (r=0.11, p=0.18). Our results reveal the correlation between color memory and color naming, both across individuals and along the hues of the color wheel.

36.3042 Study of the Japanese color lexicon using cluster analysis

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The universality of color categories has been demonstrated by various studies. A series of analyses of categorical clusters of color samples used in World Color Survey (WCS) have revealed several 'motifs,' or color naming systems (Lindsey and Brown, 2006, 2009, and 2014), which present commonly across languages. Furthermore, several motifs co-exist within a language. The motifs differ mainly at the border between the blue and green categories. In Japanese, one of the basic color terms 'ao' (translated as blue in English) is occasionally used when naming leaves of trees, traffic lights, copper rust, and etc. We investigated the basic color categories of Japanese using cluster analysis to clarify whether the color categories in Japanese show an unclear border between the blue and green categories, i.e., the 'grue' color term or the corresponding motif. We conducted a k-means analysis, in which the optimal number of clusters was determined, using gap statistics to define the optimal number of categories. 57 Japanese-speaking participants named the WCS color samples using monolexemic color terms without modifiers or compound words. We found six chromatic categories in addition to the basic color terms in Berlin and Kay (1969). They were: 'mizu (water)', 'hada (skin)', 'matcha (powdered green tea)', 'oudo (sand/mud)', 'ai (indigo)', and 'enji (reddish brown)'. The terms 'mizu', 'hada' and 'kusa (grass)' were reported as subsidiary basic terms in a study of Japanese categorical color terms (Uchikawa and Boynton, 1987). The term 'kusa' was not used in the present study, but the term 'matcha' may be a substitute. The 'mizu' cluster was consistently located at high lightness, between blue and green, suggesting that blue and green are distinct categories. However, the 'mizu' cluster is fundamentally different from the 'turquoise/teal' cluster observed in English because 'mizu' also includes many samples that most English speakers call "light blue".

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36.3043 Ad hoc color concept mapping and interpreting visual representations

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Interpreting visual representations of abstract concepts (e.g. graphs and signs) requires inferring abstract meanings from visual features (e.g., colors). We predicted that this process would be easier when the color-concept mappings in the visual representation matched observers' predictions of how colors and concept should be mapped (internal mapping). We investigated whether internal mappings can be formed from minimal exposure to new color-concept pairings in graphs (ad hoc mappings) such that they influence interpretations of subsequent graphs. The paradigm contained a series of 3-trial-blocks (one graph per trial). Bar graphs depicted fictitious data with two levels of factor A on the x-axis and two levels of factor B as different bar colors. The first two trials (learning) contained consistent color-concept mappings (e.g., b1-red/b2-blue), but the concepts in factor A varied. In each trial, participants answered a 2AFC question about the graph. The learning trials were followed by a test trial in which participants answered another 2AFC question, but the formatting of the graph varied with respect to the preceding learning trials. In Experiment 1, four possible test graphs were constructed from 2 color-schemes (same/different) x 2 factor B-concepts (same/different). Response times (RTs) were faster when test trial mappings matched learning trials (color-same/concept-same conditions) than when they mismatched (color-same/concept-different; color-different/concept-same) or were new (color-different/concept-different, ps< .05). This suggests participants formed ad hoc mappings. Experiment 2 tested whether ad-hoc mappings rely on exact color matches, or if they code relational information (e.g., lightness differences). In the learning trials, Factor B concepts were represented by bars of the same hue and different lightnesses (e.g., b1-light-blue/b2-dark-blue). The test graph conditions were 2 hue-schemes (same/different) x 2 lightness-relations (same/different). RTs were shorter when lightness relation was preserved (p< .01) regardless of hue. Therefore, ad hoc color-concept mappings store relational information, without relying on surface matches.

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36.3044 English and Somali differences in understanding of "yellow"

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A classic test of Hering's opponent-color theory of color appearance is the hue-scaling experiment (e.g., Jameson&Hurvich, 1959), where subjects perceptually decompose test colors into proportions of four fundamental hue sensations: red, green, blue, and yellow. What might this Hering decomposition look like if informants have no distinct categories for one or more of the fundamental sensations? To examine this question, we tested Somalis, some of whom used an achromatic term to name green and/or blue samples, while others used one word for blue and green. In our modified color-scaling protocol, subjects reported hue names, but not their relative proportions. We added black and white to our protocol to accommodate those Somalis who use achromatic terms for green and/or blue. U.S. (n=26) and Somali (n=37) informants first provided Hering names (HNs) for focal color examples of English red, green, blue, yellow, black and white lexical categories. Subjects then used as many of their own HNs as needed to name each of 145 Munsell samples spanning the WCS color chart, or responded "Don't Know." U.S. and Somali informants deployed their respective HNs in a manner generally consistent with a standard Hering decomposition, with the striking exception of the Somali use of yellow HNs, which extended beyond the English yellow HN boundaries to include pink, lavender, purple and often desaturated blues and greens. These results did not depend on the number of HNs available to the Somali informant. Separate multidimensional scaling experiments showed remarkable yellow-purple similarity judgments among Somali informants, but rarely among U.S. informants. Thus, Somalis and U.S. informants differ in their understanding of "yellow." Finally, we found this same pattern in the universal YELLOW category (Lindsey&Brown, 2006) among ~15% of World Color Survey informants (Kay et al., 2009), suggesting this pattern is general to many world languages.

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36.3045 Yellow is no happier than blue when lightness and chroma are controlled

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Color is important for conveying emotion, especially in art and design. However, there are commonly held notions, such as "yellow is happy" and "blue is sad," which are not well understood and can lead to erroneous assumptions. In particular, prototypical yellow is lighter than prototypical blue, so yellow-happy, blue-sad associations may actually be driven by differences in lightness, not hue. If so, then darkening yellow would make it sad and blue would be as happy as yellow if it were equally light. We tested these possibilities by having participants (n=20) judge the happiness/sadness of 32 colors (8 hues x 2 chroma levels x 2 lightness levels) controlled for chroma (C*) and lightness (L*). The colors were sampled from CIE L*C*h space (calculated from CIE L*a*b*). We found that 94% of the variance in mean ratings was explained by lightness (82%; lighter colors being happier), chroma (additional 6%; higher chroma colors being happier), and b* (additional 6%; bluer, not yellower, colors being happier). A mixed effects linear regression further revealed lightness x chroma ($p< .01$) and lightness x b* ($p< .001$) interactions. Increasing chroma and blueness made darker colors happier, but had little (chroma) or no (blueness) effect for lighter colors. However, hues of the same C* and L* do not always appear equally saturated (Fairchild, 2005) so it is possible that darker bluer colors were happier because they appeared more saturated. To test this possibility we repeated the experiment on colors with perceptually matched saturation within each lightness level (following Witzel and Franklin's (2014) procedure). We conclude that the notion of yellow being happier than blue is driven primarily by lightness, not hue, and current hue-focused attempts to understand color-emotion associations are misguided. Research on why colors have particular emotion associations should shift focus to effects of lightness and chroma.

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36.3046 Multilevel analysis reveals individual differences and the regularity of grapheme-colors associations in synesthesia

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Grapheme-color synesthesia is a condition in which visual perception of letters and numbers induces simultaneous perception of a given color. Previous studies have shown factors that affect synesthetic grapheme-color correspondence. Among them, some are systematically associated with grapheme properties: visual shape and ordinality (positions in a grapheme sequence). However, contributions of these factors differ across individuals. To understand the mechanisms underlying grapheme-color associations, we investigated whether factors determining grapheme-color associations are related to the difference in subjective experiences perceiving synesthetic colors. Some synesthetes termed "projectors," perceived their associated colors visually in external space." Others, termed "associators," perceived their colors in internal space, characterizing them as existing "in my mind's eye" or "in my head." Twenty one Japanese grapheme-color synesthetes participated in this study. Using the questionnaire by Skelton, Ludwig, & Mohr (2009), we measured the type of subjective synesthetic experience on the projector-associator continuum. We measured the color coordinates (CIE L*a*b*) of synesthetic colors for the 26 alphabetical letters using a color-matching task. We obtained the data for visual shape similarity and ordinality from previous studies. Then we conducted a multilevel analysis with hue distance of synesthetic colors as dependent variables, visual shape similarity and ordinality as within-participant level independent variables, and synesthetic experience as inter-participant level independent variables. The results showed that individual differences in intercepts and slopes at the within-participant level could be explained by a parameter at the inter-participant level. Namely, the factor of the ordinality was expressed more strongly with associators than projectors. This finding suggests that grapheme-color associations are partly determined by the type of synesthetic experience spanning from projectors to associators.

36.3047 Color perception in ASD

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Color perception in Autism Spectrum Disorders (ASD) has been shown to be weaker compared to typically developed individuals (TD) in some studies, while enhanced in others. We compared the perception of color in individuals with ASD and in TD looking for both quantitative and qualitative differences. Individual thresholds were first measured using adaptive procedures separately for hue, saturation, and brightness, revealing no differences in thresholds between the two groups, in any of the three dimensions of color. The classical Garner tasks were employed to examine whether the typical integral perception of color is also shown in ASD. Performance in the speeded classification task showed interference from an irrelevant dimension (e.g., hue) when perceptually classifying a different, relevant dimension (e.g., brightness), suggesting integral perception of hue, brightness, and saturation in ASD. Performance in the restricted classification task showed that both classification rates based on overall similarity (integral) of stimuli differing on two color dimensions (e.g., hue and saturation), and classification rates based on dimensional identity (separable) of stimuli differing on the separable dimensions (e.g., size and brightness), were relatively lower in ASD. Furthermore, when asked explicitly to classify color based on just one separate dimension (e.g., brightness), ASD showed enhanced performance compared to TD. Altogether the results suggest an intact sensitivity to color in ASD and a typical integral processing of the different dimensions. However, contrary to TD, individuals with ASD show enhanced separable perception of the different dimensions of color along with the availability of their integral representation.

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36.3048 Chromatic blur perception in simple and complex stimul

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In a compelling demonstration Wandell (1995) showed that blurring the chromatic but not luminance layer of an image of a natural scene failed to elicit any impression of blur. Subsequent studies have suggested that the effect is due either to masking of the chromatic blur by the sharp luminance edges in the image (Sharman et al., 2013) or to a relatively compressed transducer function for chromatic blur (Kingdom et al., 2015). To test between these alternatives we first measured points of subjective equality (PSE) and precisions (thresholds) for Gaussian blurred circles. Perceived chromatic blur was found to be equal to perceived luminance blur, and was independent of contrast level. Introducing a sharp luminance step-edge had no effect on the perceived level of chromatic blur. However, in a subsequent experiment using images of natural scenes, the perceived blur of the chromatic layer was reduced in the presence of the luminance layer, as was also the chromatic blur precision (thresholds), in keeping with the results of Sharman et al. (2013). Yet, when the luminance layer was rotated relative to the chromatic layer, which removed the color-luminance edge correlations, chromatic blur precision was even worse, even although PSEs were restored to near-veridicality. We conclude that both luminance masking and chromatic scale compression contribute to the Wandell effect.

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36.3049 The dark is more (Dark+) bias in colormap data visualizations with legends

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Colormaps represent data by mapping dimensions of color (e.g., lightness) onto quantities (e.g., amplitude in spectrograms, correlation in correlation matrices, and activation in neuroimages). Does the specific assignment between poles of the color dimension (e.g., dark vs. light) and poles of the quantity dimension (e.g., more vs. less) influence observers' ability to interpret colormap data visualizations? There is a robust bias to interpret darker colors as mapping onto larger quantities (Dark+ bias) when no legend specifies the true mapping (Schloss, Gramazio, & Walmsley, VSS-2015), but does the Dark+ bias persist when a legend explicitly defines the color-quantity mapping? We addressed this question by comparing participants' response times (RTs) to correctly interpret colormaps when a legend specified dark+ (greater quantities coded as darker) vs. light+ (greater quantities coded as lighter) mapping. We operationalized the Dark+ bias as faster RTs for dark+ than light+ mappings. Participants were presented with fictitious data matrices where columns represented time, rows represented alien species, and cell color represented how often each species was spotted during each time window. To respond, participants interpreted the legend and then reported whether there were more animal sightings early vs. late. We presented the legend in each of four conditions: 2 color quantity mappings (light+/dark+) x 2 orientations ("greater"-higher/"greater"-lower). Colormaps were constructed from the orthogonal combinations of 5 color scales (ColorBrewer Blue/ColorBrewer Red/Hot/Autumn/Gray/Jet) x 2 background colors (white/black) x 2 sides for darker color (left/right) x 20 replications (total of 1600 trials). Consistent with the Dark+ bias, RTs were significantly faster when the legend specified dark+ mapping ($p< .001$). This bias is contrary to the common, light+ mapping

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in neuroimages (Christen et al., 2013). The results indicate that observers have predictions about how colors should map onto quantities, and data visualizations that violate those predictions are more difficult to interpret.

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36.3050 Eye-movement patterns betray the task at hand in colour judgements Simon Cropper[1](scropper@unimelb.edu.au), Jason Forte[1], Ruirong Mao[1]; [1]Melbourne School of Psychological Sciences, University of Melbourne, Australia, 3010

It has been suggested that eye-movements both betray and influence the chosen stimulus in a judgement of facial attractiveness. We were interested in generalising this observation to see whether patterns of eye-movements would change according to the type of decision to be made when faced with a series of binary choices made with the same stimulus set. Two 4deg colour patches were presented 4deg either side of (temporary) fixation. The suprathreshold patches were defined along a vectors in CIE space between 'red' and 'green' centred on 'yellow'. The stimuli were either modulated in colour or luminance and the subject required to respond using a keypress. Eye-movements were recorded monocularly with an EyeLink2 at 250 samples/sec with a spatial resolution of 0.1deg. In separate blocks of the same stimulus set, subjects (n=18) were required to decide if the patches were the same or different (discrimination), which was redder, which was brighter, and which they preferred. Stimuli remained on the screen until the decision was made and eye-movements were recorded for the duration. Our main finding is that the pattern of eye-movements, in terms of position, number and duration of fixations, are uniquely related to the task at hand. Eye-movements were influenced both by the difficulty of the task and whether it was a judgement of colour or luminance difference. When the task was one of preference, the eye-movements did not reflect the pattern seen for facial attractiveness, but were distinct from that of discrimination, or from judgements of colour or luminance. We conclude that eye-movements do provide insight onto the underlying processes of stimulus analysis and decision, but in a way that reflects an ongoing interaction between stimulus- and task-based influences.

Color and Light: Surfaces and materials

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4001 Estimating material properties of cloth from dynamic silhouettes Luis Bermudez[1](bermudez.luis3d@gmail.com), Bei Xiao[1]; [1]Department of Computer Science, American University, Washington DC

Deformable materials such as cloth exhibit most of their mechanical properties (e.g., stiffness) from motions caused by external forces. Previous research shows that humans can estimate mechanical properties of cloth by observing its motions. However, it is unclear how dynamic behavior alone can convey mechanical properties without the appearance of surface textures and surface reflectance. Here, we extracted silhouettes of moving cloth under wind forces from videos. We hypothesize that the motion of silhouettes alone can be a sufficient cue to allow estimation of cloth mechanical properties. The experimental stimuli are videos of hanging cloth subject to wind forces. We conducted two experiments via Amazon Mechanical Turk. At each trial, a user is presented a pair of videos (which contains two different cloth samples) and is asked to predict which cloth has a higher bending stiffness. 85 users finished 1800 paired-comparisons (300 trials * 3 repetitions * 2 Experiments). The first experiment used the original videos of the hanging cloth. The second experiment used videos with the same subjects, but only presenting the silhouette of the cloth. Silhouettes are constructed by extracting the outline of the cloth at each frame. By presenting only the silhouette, we remove other visual cues (such as textures and reflectance) and isolate the dynamic motion. Overall, the cloths were perceived with similar accuracy (60% across all trials) for the original videos and the silhouette videos. Also, both experiments had better accuracy when the difference between cloth samples was larger (the difference being measured by bending stiffness). The results show that dynamic silhouettes can be sufficient to perceive mechanical properties of cloth without surface information such as textures for most cloth samples. This indicates that it is possible to only simulate the dynamics (without photorealistic rendering of detailed textures) to maintain perception of mechanical properties of cloth.

36.4002 Effects of stimulus duration on surface quality perception Naozumi Yamada[1](tmc63920@st.yamagata-u.ac.jp), Yuki Kawashima[1], Yasuki Yamauchi[1], Takehiro Nagai[1]; [1]Department of Informatics, Yamagata University

Humans can quickly perceive various surface qualities such as glossiness and heaviness. Also, it seems intuitively plausible that complexity of image information contributing to perception are largely different across surface qualities; for example, perception of glossiness may depend on simpler image information such as low-level image statistics than heaviness. In this study, we psychophysically measured effects of stimulus durations on perception of different surface qualities as an index of complexity of image information contributing to perception. In the experiment, two of the 35 material samples were simultaneously presented on an LCD monitor for a duration in the range from 34 ms to 150 ms. The observer judged which of the two samples gave stronger perception of a certain surface quality with a 2AFC procedure (e.g., which one gave "stronger glossiness"). Seven surface qualities such as glossiness, warmness, and heaviness were employed as target qualities. Preference scale values were calculated on the basis of Thurston's scaling method for pairwise comparison as measures of perceived strength of surface qualities. In the results, magnitudes of effects of stimulus duration were significantly different between surface qualities; some surface qualities such as glossiness and warmness were well judged even under short durations, while other qualities such as heaviness were not. In an additional analysis, we calculated 23 low-level image statistics from the material samples used in the experiment and investigated relationship with surface quality perception. The analysis showed that perception of surface qualities, which were not strongly affected by stimulus durations, tended to be strongly related with low-level image statistics. For example, warmness was strongly related to mean chromaticity regardless of the stimulus duration. These results suggest that complexity of image information contributing to surface quality perception may considerably differ across various surface qualities, and specific surface qualities may strongly depend on simple image information.

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36.4003 Visual communication of haptic material properties Maarten Wijntjes[1](m.w.a.wijntjes@tudelft.nl), Bei Xiao[2]; [1]Perceptual Intelligence lab, Industrial Design Engineering, Delft University of Technology, [2]Department of Computer Science, American University

There are many circumstances in which we are unable to touch an object, for example during online shopping. This can be a serious problem when the haptic qualities are an important aspect of the product experience. Here, we investigated whether this inability to touch can be alleviated by using a visual substitute. In Experiment 1, we measured visuo-haptic matching of fabric samples. Nine pieces of jeans were filmed in six different styles (e.g. hands pinching cloth or a downward flutter movement). Twenty observers matched haptically presented fabrics to the visual representations. Ten observers were shown the actual movies, and the other ten served as a control group that was shown stills from the movies. Results indicate that movies enrich the sensorial information sufficiently to improve the prediction of haptic apparel properties, although the effect is modest. In Experiment 2, we compared haptic similarity judgments of all possible cloth pairs, with visual estimations of haptic similarities. We hypothesized that haptic judgments would be closer to the visual judgments based on movies, than those based on merely movie stills. A total or 32 observers participated in this experiment: 16 based their judgments on haptic perception, 9 on the movies and 7 on the pictures. Results revealed high correlations (r~0.8-0.9) between the two visual conditions. Surprisingly, we found no correlation between the similarity judgments based on visual information with the similarity judgments based on haptic information. These results were rather constant over the various movie styles. The result of Experiment 2 implies that observers perceive the haptic qualities of fabrics differently when actually touching then through their visual substitutes. Thus, although performance improved (Experiment 1) for dynamic visual information as opposed to static, the visual communication of haptic properties has to be further improved to optimally match actual haptic sensations.

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36.4004 Probing the illumination on #The Dress Matteo Toscani[1](matteo.toscani@psychol.uni-giessen.de), Katja Dörschner [1], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

"The colour-changing dress" is an internet phenomenon in which the colours of a dress are reported to be different by different people. In previous works (e.g. Winkler et al. 2015, Lafer-Sousa et al. 2015, Brainard and Hurlbert 2015, Gegenfurtner et al. 2015) this striking ambiguity was interpreted within the colour constancy framework, where the colour of a surface is perceived after estimating and discounting the colour of the illuminant (e.g, Foster 2011, Boyaci et al., 2006). Here we explicitly test the hypothesis that people who reported different colours of the dress also perceived different illuminations. We measured this by introducing a probe (Koenderink et al. 2007), a sphere, in two positions within the scene and letting the observers adjust its appearance. Twenty-four observers adjusted the colour, the intensity and the direction of the illumination of the probe rendered in front and in the background of the dress in the original scene. Observers' task was to adjust the probe to appear as a white sphere embedded in the scene. We found that people who reported the dress to be white tended to produce bluer adjustments than people who reported it as blue. A computer classification approach on the two chromatic dimensions of DKL colour space (LM & S) allowed us to classify the two groups of people with 67% accuracy, and t-tests show a significant difference in the colour adjustments along the LM dimension ($p < 0.05$) and at the edge of statistical significance on the S axis ($p=0.067$). There were no differences in the adjustments of the background probe. These results are compatible with the idea that the ambiguity in the perceived colour of the dress can be explained by the different assumptions that people made about the illumination of the scene in which the dress is embedded.

36.4005 **Perceptual segregation between mirror and glass material under natural and unnatural illumination** Hideki Tamura[1](tamura13@vpac.cs.tut.ac.jp), Maki Tsukuda[1], Hiroshi Higashi[1], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology

When we recognize a surface material of an object, the scatter distribution from light on its surface can be one of the cues in natural environment light fields (Fleming et al., 2003). We investigated what cues are used when the human visual system is possible to distinguish between "mirror" and "glass" objects under natural and unnatural illumination. Various shaped objects with completely specular reflected surface ("mirror"), and with transparent and refraction components ("glass") were generated by computer graphics. These stimuli were rendered under several real-world (Debevec, 1998) and unnatural illumination composed of binary random noise. Stimuli were presented for 1,000 ms while the object was just standing (static condition) or horizontally rotating (dynamic condition). Human observers were asked to judge its object material (mirror or glass) in a 2AFC paradigm. Under the natural illumination, the performances in the static and the dynamic condition were 75% and 89% showing that observers could perform mirror-glass discrimination even in the static condition and motion information helped the discrimination to some extent. Under the unnatural illumination, however, observers could not judge the object material in the static condition (57%). In the dynamic condition, the performances raised to approximately same level as the performance in the static condition under the natural illumination (78%). We found the similar tendency when observers judged under the natural illumination with color negative/positive inversion in which spatial structure of the reflection remains unchanged. These findings suggest that while static distorted reflection itself does not help to distinguish between mirror and glass under the unnatural illumination, motion information of the distorted reflection of the mirror and glass can be a relevant cue to distinguish them.

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36.4006 **Simultaneous Representation of Shape and Material --- Adaptation to Material Alters the Perception of Depth ---** Ko Sakai[1](sakai@cs.tsukuba.ac.jp), Takeshi Oyakawa[1]; [1]Dept. Computer Science, University of Tsukuba

The human visual system infers simultaneously surface reflectance, object shape, and lighting from an image projected onto the retina. It remains to be clarified how the visual system solves this ill-posed problem. To approach this problem, we investigated whether the visual system represents simultaneously material qualities and object depth. Specifically, we examined whether the adaptation to a specific material alters the perceptual depth of an object that consisted of the material. If the adaptation to a material alters the perceptual depth, simultaneous representation of material quality and object depth is suggested. This will lead to a prediction that a neuron, or a neural circuit, is co-selective to material and depth. To test the hypothesis, we rendered high-dynamic-range images of a bumpy surface with a specific reflectance/material (Bidirectional Reflectance Distribution Function). A pair of the images was presented simultaneously for adaptation, with their BRDFs far apart in the perceptual gloss space (Contrast gross & Distinctness-of-image gloss). The degrees of bumpiness were adjusted so that their perceptual depth was identical. For test, we presented another pair of stimuli with the BRDF in-between those used in the adaptation. Each stimulus had distinct depth of bumps, and participants were asked to judge which surface appeared deeper (constant stimuli method). The results showed the significant difference in the perceptual depth between the pre- and post-adaptation, indicating that the adaptation to material suppressed the perception of depth. We obtained similar results in the control experiment in which the matte stimulus was replaced by the synthesized stimulus (Portilla & Simoncelli, 2000) so that early-level features were identical with the gloss stimulus but apparent material was matte, denying the adaptation to early-level features. The present results support the hypothesis that the visual system represents simultaneously shape and material.

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36.4007 **Color and material trade-off in object identification** Ana Radonjić[1](radonjic@sas.upenn.edu), Nicolas Cottaris[1], David Brainard[1]; [1]Department of Psychology, University of Pennsylvania, USA

Color helps identify objects, but the role it plays in identification relative to other object properties, such as material, texture or shape, is not well understood. To study this, we developed a novel selection-based method. Here we describe how we used it to quantify the relative contribution of color and material to object identification. The stimuli consisted of a set of blob-shaped objects rendered using RenderToolbox3. The objects varied in color (7 levels, from green to blue) and material (7 levels, from specular to matte). One of the objects (level 4 in both color and material) served as the target. On each trial, subjects (N=5) viewed the target together with a pair of test objects drawn from the set. One test object differed from the target in material only (material lure), while the other differed from the target in color only (color lure). Across trials, the size of the material and color differences was varied in a crossed design. Subjects judged which lure appeared more similar to the target and we measured the fraction of trials on which the material lure was chosen over the color lure for each of the material/color difference pairs. We found that subjects exhibit a smooth trade-off between color and material as cues to object identity: the more the color lure differed from the target, the more likely subjects were to choose the material lure. Similarly, the more the material lure differed from the target, the more likely subjects were to choose the color lure. We used the data to quantify the relative importance of color and material cue for each subject. This varied systematically across subjects. Our method enables us to characterize how different object properties are used in identification, and thus measure any reweighting of these properties as their reliability varies.

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36.4008 **Visual cues to stiffness of elastic objects** Vivian Paulun[1](Vivian.C.Paulun@psychol.uni-giessen.de), Jan Jaap van Assen[1], Roland Fleming[1]; [1]Department of Psychology, Justus-Liebig-University, Giessen, Germany

Non-rigid materials such as rubber or jelly respond to external forces by bending, bulging and wobbling in distinctive ways. These characteristic motions and shape changes could provide visual cues to the material's stiffness. However, there is an inherent ambiguity between the amount of force applied and the physical parameters of the object, as both factors contribute to the resulting deformations. We simulated two sets of scenes in which we varied both the softness of a cube, and the depth that a rigid cylinder was pushed into the cube (i.e. simulating an external force). In one scene, the cylinder was pushed into the cube from above and the simulation stopped when the perturbation reached its maximum depth. This allows us to isolate shape-related cues to stiffness. In the second scene, the cylinder was pushed in from behind the cube (invisible to the observer) and the animation only showed what happened after the cylinder was quickly removed. This emphasises motion-related cues to stiffness. Observers rated the apparent stiffness of the cubes. In the first scene, ratings were almost completely dominated by the magnitude of the perturbations (rather than the intrinsic material properties of the cube). This is consistent with observers assuming the cylinder acted with constant force, and attributing differences in deformation to differences in softness. Thus, although not invariant across different interactions, the depth of the shape deformation was used as a visual cue to softness. If, on the other hand, motion was the dominant feature in a scene, softness perception depended less on the shape deformation but strongly on the amplitude and frequency of the object's motion. An analysis of the geometries of the simulated cubes revealed several cues related to curvatures, and frequency and damping of oscillations, which correspond well with the perceptual ratings of stiffness.

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36.4009 Perceived chromatic diversity in dichromacy benefits from the color distributions of natural scenes

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Inherited color vision deficiencies impair color discrimination and therefore impoverish the chromatic diversity perceived in natural scenes. For dichromacy, estimates based on hyperspectral imaging data from natural scenes and assuming Brettel's perceptual model, suggest a reduction in the number of perceived colors of about 93%. These estimates, however, do not take into account the actual distributions of colors in the scenes. Pairs of colors confused by dichromats may be rare and thus have small impact on perceived chromatic diversity. The purpose of this work was to estimate, empirically, how dichromacy impairs discrimination of pairs of colors in natural scenes. The stimulus for the experiment was a scene made of 3D objects painted with matte white paint. The scene subtended 10 deg and was set inside a light booth illuminated by a spectrally tunable light source based on the Digital Light Processor technology (OL 490 Agile Light Source, Gooch & Housego). The spectral composition of the light source could be tuned very fast with a spectral resolution of 20 nm using in-house software. In each trial of the experiment the observer first adapted for 1 s to the white standard illuminant E. Then, two spectra drawn randomly from hyperspectral data from one of four natural scenes, illuminated in succession the booth interior for 1 s each, with a dark ISI of the same duration. The observers had to indicate whether the spectra were the same or different. Four color normal observers and two dichromats carried out the experiment. It was found that the number of pairs that could be discriminated by dichromats was about 50% of those discriminated by normals, a fraction much higher than anticipated from estimates of discernible colors. This result suggest that the color distributions of natural scenes benefit the color vision of dichromats.

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36.4010 Effects of specular highlight on color constancy: appearance setting vs paper setting

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Specular highlight on object surfaces is a candidate cue for color constancy, because in many cases it directly reflects spectral components of illuminants in the scene. Previous studies reported small effects of specular highlight on color constancy for human observers. In this study, we further investigated effects of specular highlight on color constancy in the black background, which suppresses strong effects of background color adjacent to a target object. In our psychophysical experiment, the stimulus was composed of a test object at the center of an LCD monitor and its surrounding objects, which gave observers illumination cues, on a black background. The luminances and chromaticities of the surrounding objects were set so that their surfaces with spectral reflectance of Munsell color chips was illuminated by D65, A, or 25000K illuminant. In addition, we had two conditions about glossiness of the surrounding objects: Gloss (with specular highlight) and Mat (without specular highlight) conditions. The observer conducted two kinds of tasks for the stimulus. One task was appearance achromatic setting, in which the observer adjusted the chromaticity of the test object so that its appearance became achromatic. The other was paper achromatic setting, in which the observer adjusted the test chromaticity so that its appearance matched a gray object illuminated by the scene illuminant. The results of appearance setting demonstrated slight improvement of color constancy for the Gloss condition than the Mat condition, as expected from the previous studies. In addition, the effect of gloss was much larger for the paper setting than the appearance setting. These results support the previous studies in that effects of specular highlight on color appearance shift due to color constancy are small, and suggest its much stronger effects on recognition of scene illuminant

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36.4011 Joint estimation of surface gloss and 3D shape

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Visual estimation of material properties is an ill-posed problem: an object's image varies with surface reflectance, but also with illumination and 3-D surface geometry. Previous studies have shown that perceived gloss depends on 3-D surface geometry: bumpier surfaces are often perceived to be glossier. In addition, surface gloss can modulate perceived shape. Are shape and reflectance jointly estimated? Here we ask whether human perception reflects a generative model such that errors in one property predict errors in the other. To this end, we determined quantitative estimates of perceived shape and perceived gloss for the same stimuli. We generated two sets of physical objects: one varied in gloss and one in bumpiness (depth extent). Mixtures containing different proportions of matte and glossy varnish were applied to spheres resulting in eleven gloss levels. To estimate the reflectance characteristics of these objects, we determined the surface reflectance parameters of the Ward model that minimized the difference between photographs of the objects and rendered images. 3D printing produced eleven arrays of random-height ellipsoids varying in bumpiness (depth range). Observers reported the perceived glossiness and bumpiness of computer-rendered ellipsoid arrays by referencing the physical objects. Glossiness and bumpiness of the rendered objects varied independently across trials. Rendered stimuli were viewed monocularly without head movements. In contrast, the physical objects, lit with ambient and direct light, were viewed binocularly with unrestricted viewing. Gloss judgments increased as a function of both physical gloss and physical bumpiness. Although perceived bumpiness was largely independent of physical gloss, bumpiness was increasingly underestimated as depth increased. Thus, observers indeed estimate shape and gloss jointly: underestimation of shape is coupled with overestimation of gloss, consistent with the effects of these two variables on images of physical objects.

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36.4012 Peripheral material perception

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Humans can rapidly detect and identify materials, such as a hardwood floor or a smooth leather jacket, in a visual scene. Prior research shows that visual texture plays an important role in how humans identify materials. Interestingly, recent models of peripheral vision suggest a texture-like encoding. This might mean that textures are well represented by peripheral vision, and therefore a natural question to ask is how well materials are perceived in the periphery, and whether that peripheral vision model can predict this performance. We present windowed grayscale images of materials from the Flickr Materials Database (photos of various materials from different scales and viewpoints) briefly to 8 human subjects at 10 degrees visual eccentricity. Subjects categorized each image (50 per category) into one of 6 material categories (fabric, foliage, leather, stone, water, and wood). To generate model predictions, we synthesized images with the same texture statistics as the original, using Portilla-Simoncelli texture analysis-synthesis. Subjects free-viewed these synthesized images and also performed the material classification task. (Note that the full version of the model would extract statistics from multiple overlapping regions, not from a single region as here.) We found small but significant correlation between the peripheral and synthesized conditions. This provides evidence that the model can predict peripheral vision, including material perception. Each subject was well above chance in both conditions. Visual inspection of the individual stimuli seems to suggest that images in which peripheral vision is better than the synthetic versions contain more large-scale shape cues, such as water droplets and individual leaves (foliage). Both viewing conditions seemed to be performed well when images contained more small-scale texture properties, such as wooden or stone surfaces. Importantly, we examined performance for individual stimuli between subjects. There is a huge range in performance in both conditions, which we discuss in detail.

36.4013 Can people match optically mixed canonical lighting modes?

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We previously developed a material probe, namely MatMix 1.0, and found it to be an intuitive tool to robustly quantify visual material perception (Zhang et al., VSS 2015). Using MatMix 1.0, we found that varying illu-

Sunday PM

mination systematically influenced the material perception, depending on the materials (Zhang et al., SPIE 2015). In this study, MatMix 1.0 was adjusted to MixIM 1.0 (Mixing Illumination and Material) and used in a matching experiment to quantify visual perception of canonical lighting modes. Three types of canonical lighting modes (so-called ambient, focus, and brilliance light) and four types of canonical material modes (matte, velvety, specular and glittery) were included. A stimulus image and the probe were shown together. The probe was a linear weighted optical mixture of three basis images under three canonical lightings of one of the canonical materials. Below the probe, three sliders represented the canonical lightings. The appearance of the probe could be changed by the observer moving the sliders and the weight of each lighting mode changed accordingly. The task for the observers was to match the illumination of the material in the probe with that of the material in the stimulus, without time limits. The materials could be the same or different. When materials in the stimulus and the probe were the same, all 8 observers performed far above chance level. When the materials were different, the performance of all observers decreased. 7 of 8 observers still performed far above chance level, except when the velvety mode was present in the stimulus, for which performance was only slightly above chance level In conclusion, we found that observers could match the illumination of a stimulus and a probe by mixing three canonical lighting modes and that material differences decreased matching performance, especially if a velvety mode was present.

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36.4014 **The sensitivity of the human visual system to subtle skin tone changes**

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Skin reflectance can be modulated along two dimensions by haemoglobin: varying the haemoglobin oxygen saturation or the haemoglobin skin concentration. Changes in haemoglobin oxygen saturation leads to specific changes in the reflectance spectra (a 'W' spectral signature; Changizi et al., 2006, Biol Lett. 2, 217) and is associated with a colour shift towards red. Changizi et al. argue that trichromatic vision may be optimised for discerning small colour changes associated with haemoglobin oxygenation. We tested this hypothesis in two ways. We first analysed a large data set of skin spectra to test whether this spectral signature of oxygenated haemoglobin is present, and whether it depends on body location. Another prediction is that human observers should be particularly sensitive to small colour changes consistent with the oxygen saturation of haemoglobin. To test his hypothesis, we conducted a psychophysical discrimination experiment with calibrated skin images to obtain thresholds in 8 different isoluminant colour directions including the direction associated with haemoglobin oxygenation. Analysis of skin spectra obtained from 188 participants show that the 'W' feature is indeed present in the skin spectra, with troughs at about 540 and 575nm and that the 'W' feature is most prominent in the cheek area compared to the neck area and to the forehead. These findings are consistent with the idea that the human colour system is optimised to detect oxygenation changes. In contrast, our preliminary psychophysical experiments do not show a greater sensitivity in the direction association with oxygen saturation of haemoglobin. Based on our preliminary analysis, we find partial support for the hypothesis that our visual system is optimised to discern small changes in facial redness which are diagnostic of mood and health states.

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36.4015 **Toddlers' Discrimination of Shadow and Reflectance**

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Studies investigating the development of shadow perception demonstrate that by 7 months, infants are sensitive to shadow information; they perceive depth from shadows (Imura et al., 2006; Yonas & Granrud, 2006) and detect incongruencies in an object's shape and the shadow it casts (Sato et al., 2015). However, distinguishing shadow patterns viewed on the surface of objects from patterns created by object properties (i.e., reflectance) in the absence of a visible caster is a more challenging task and one that has not yet been assessed in infants. The current study investigated the development of this ability using a preference task. Toddlers (23- and 30-month-olds, N = 32) were presented with two toy eggs, one with dots and the other without. The plain egg was opened to reveal an entertaining chirping bird. After initial exposure, the eggs were placed on a stage equidistant from the toddler (counterbalanced placement) in a baseline condition used to ascertain the child's initial preference. Test trials were identical except to simulate shadows, dots were projected on the surface of the plain egg. Selecting the correct toy required the child identify the plain egg even when the shadow pattern was projected onto it. Percent correct scores were analyzed using a one-way ANOVA revealing statistically significant differences by age at $p < .001$, □p2 = .41 with the older infants succeeding more frequently. Furthermore, the 23-month-olds' scores did not differ significantly from chance, $t(15) = 0.22$, $p = .83$ (M = 52%), whereas the 30-month-olds' did, $t(15) = 18.15$, $p < .001$ (M = 96%). These results indicate that only the 30-month-olds readily identified the egg with the chick inside, suggesting that the ability to distinguish shadow patterns from reflectance patterns in the absence of a caster emerges between 23 and 30 months of age.

36.4016 **Image statistics and the affective responses to visual surfaces**

Isamu Motoyoshi[1], Shiori Mori[1]; [1]Department of Life Sciences, The University of Tokyo

Humans are not only able to perceive physical properties and material of natural surfaces, but also judge their emotional values, which would afford attraction toward, or aversion from, particular surfaces. To investigate visual process underlying such emotional responses, we asked human observers to assess comfortableness and unpleasantness for 193 images of natural surfaces that included clothes, foods, skin, stones, liquid, trypophobic stuff, and so on. We analyzed the relationships between the rating data and image statistics of these stimuli in the cone-contrast space (Lum, RG, and YB channels). The analysis revealed that, for all color channels, the SD at mid-spatial frequency bands and the cross-orientation energy correlation at high-spatial frequency bands were correlated positively with unpleasantness and negatively with comfortableness, respectively ($p< 0.01$). It was also found that comfortableness was negatively related with the luminance vs. color correlation at high-spatial frequency bands ($p< 0.01$). We obtained similar patterns of the rating data when we used PS texture images synthesized from the original images ($r = 0.76$ for comfortableness and $r = 0.77$ for unpleasantness, respectively) or phase-scrambled images ($r = 0.68$ and $r = 0.69$), and when we presented stimuli for a short duration (50 ms) so that observers could hardly recognize the surface category ($r = 0.77$ and $r = 0.73$). These results indicate that human emotional responses to natural surfaces largely, not entirely though, depends upon relatively low level image statistics. We suggest visual mechanisms that may utilize textural information to directly summon emotional reactions for surfaces preceding the recognition of their material category.

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36.4017 **The chromatic diversity of art paintings**

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The chromatic diversity of natural scenes has been quantified from hyperspectral imaging data. Do artistic paintings mimic the same color diversity found in natural scenes? The purpose of this work was to analyze and compare the chromatic diversity of natural scenes and art paintings. Fifty images of natural scenes and 43 images of art paintings were digitized using a hyperspectral imaging system composed by a monochromatic CCD camera and a fast tunable filter capable of a spectral resolution from 400 to 720 nm in 10 nm steps. The images contained reflectance data, estimated from a grey reference with known reflectance presented at the scene at the time of acquisition. The radiance was then estimated for each pixel of the images assuming the CIE D65 illuminant. The chromatic diversity was assumed to be the number of discernible colors (NDC) in each image. The NDC was computed by representing all the image's pixels in the CIELAB color space and by segmenting it into unitary cubes. It was assumed that all the colors that were inside the same cube could not be discernible, and by counting the number of non empty cubes the NDC was obtained. It was found that the chromatic diversity in the form of NDC of the art paintings is different from that of natural scenes. The distributions of colors indicate that paintings are richer chromatically than natural scenes. This result suggest that artists are capable to generate richer chromatic information despite the gamut limitations imposed by the pigments used. Acknowledgement: This work was supported by FEDER through the COMPETE Program and by the Portuguese Foundation for Science and Technology (FCT) in the framework of the project PTDC/MHC-PCN/4731/2012.

3D Perception: Shape and cue combination

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4018 Can presenting images behind the screen plane generate a sense of stereoscopic scene depth?

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Introduction Stereoscopic (S3D) content is expensive to produce, especially in live-action where it requires the use of expensive camera rigs to capture images from two different viewpoints without introducing misalignments or distortions. Accordingly, commercial producers sometimes use a trick to generate short amounts of cheap "S3D" content from 2D content: they shift the 2D content horizontally left (right) by a fixed amount to produce content for the left (right) eye. Geometrically, this content is depicted on a planar surface behind the physical screen plane. Anecdotally, this manipulation is said to permit an impression that the scene is being viewed in S3D, presumably because it permits monocular depth cues such as motion parallax, occlusion and shading to dominate. Methods 9 participants viewed 13 30-second clips from the S3D production "Micro Monsters" in four different configurations: Natural S3D (the original content); Natural 2D (unedited, taking the left eye of the S3D clip); Translated S3D (the original content with a fixed horizontal shift applied in opposite directions to left and right-eye images) and Translated 2D (a fixed horizontal shift applied in opposite directions to the original left-eye image, to generate a new left and right image-pair). The 52 resulting clips were presented in a random order on an LG passive 3D television, while an eyetracker measured eye position. After each clip, participants were asked to rate the impression of depth on a 7-point Likert scale. Results Participants rated both types of S3D as having significantly better depth than 2D. There was no difference between Natural 2D (median 4) and Translated 2D (median 4); p=0.07 (Wilcoxon signed-rank). Eye movements also differed between S3D and 2D. Conclusion This industry trick does not fool the audience: applying constant parallax so as to present 2D video content behind the screen plane does not make it appear S3D.

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36.4019 Depth Constancy in the Apparently Circular Curvature Task with 3D Printed Stimuli

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One technique used to study the subjective quale of perceived depth magnitude is the apparently circular curvature (ACC) task in which observers view a hemi-cylinder and report whether the depth (radius) is more or less than half of the height (diameter). Prior studies using computer-generated, stereoscopic, random-dot ACC stimuli have found the radius/diameter matching point changes with viewing distance, suggesting a lack of depth constancy. We used 3D printed, grey plastic hemi-cylinders to study depth constancy. Viewed on edge, hemi-cylinder width was 130 mm, diameter was 100 mm, and depth (radius) was varied between 40 and 60 mm, in 1.25 mm steps. Stimuli were front-illuminated with 120 cm of bright-white LED tape generating 1.6k lux illumination. Observers viewed the stimuli through an experimenter-controlled ferro-electric window at three distances: 53.5, 107, and 214 cm. Using a constant-stimulus paradigm with the ACC task, observers viewed stimuli in four different conditions: monocular/stationary, monocular/motion parallax, binocular/stationary, binocular/motion parallax. Psychometric functions revealed that at all distances, and all viewing conditions, the average matching radius was between 49 and 52 mm. The average standard deviations of the functions varied between 28 mm (monocular/stationary/107cm) and 2.2 mm (binocular/motion parallax/53.5cm). Using ascending and descending method of limits with both monocular/stationary and binocular/stationary viewing, average matching was between 50 and 51 mm at all three viewing distances. These results suggest accurate depth constancy with physical 3D objects and bright viewing conditions. To explore the discrepancy with previous results, a projector mounted just below the observer's line of sight projected random-dots upon the 3D figure at 214 cm viewing distance. The matching point was typically increased between 50% and 80%, similar to previous results. This suggests that previous failures of depth constancy may have been affected by a depth cue-conflict with the flat texture of random-dots comprising the ACC stimulus.

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36.4020 The Visual Aesthetics of Snowflakes and Solid Objects

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Research on experimental aesthetics has been conducted since the nineteenth century. Interestingly, however, few studies have examined the perceived beauty of naturally-shaped objects. In the first experiment, 204 observers were presented with a set of ten snowflake silhouettes that varied in complexity (perimeter relative to area); they were similarly presented with ten randomly-shaped, computer-generated, solid objects that also varied in complexity. For each stimulus set, the observers selected the single snowflake or solid object that was the most beautiful (Fechner's method of choice). The results for the solid objects replicated the findings of earlier research: the most and least complex objects were chosen as the most beautiful. Moderately complex objects were rarely selected. The results for the snowflakes were different. For these visual stimuli, the least complex snowflakes were almost never chosen; only the complex snowflakes were perceived as being most beautiful, with the aesthetic preference increasing with increases in complexity. The distributions of aesthetic preference for snowflakes and solid objects were significantly different ($\chi2(9)= 83.1$, $p < .000001$). The second experiment assessed the perceptual validity of the measures of stimulus complexity used in Experiment 1. Observers viewed the same snowflake or solid object images that were used in Experiment 1 and rated their complexity using a scale from 1 (least complex) to 10 (most complex). The resulting average Pearson r correlation coefficients relating objective and perceived complexity were 0.834 and 0.933 for the snowflakes and solid objects, respectively. Taken together, the results of both experiments demonstrate that there is a systematic and consistent relationship between the human visual perception of beauty and objective measures of stimulus complexity.

36.4021 Large individual differences in the weighting of perspective and stereoscopic information in slant perception; implications for cue combination approaches.

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Previously unpublished individual data are presented for 12 participants in a cue conflict experiment (Gillam 1967). Stimuli were three frontal plane perspective patterns of dotted lines. Visual angle extents were 15 deg (H) and 9 deg (V). Distance was 56 cm. One pattern had equally-spaced vertical lines, one equally-spaced horizontal lines and the other a combination (grid). Stereoscopic slants around a vertical axis ranging from 4 to 33 deg. were imposed by uniocular horizontal magnification using aniseikonic lenses, creating conflict with the frontal plane perspective. A monocular comparator, validated using full cue slants, recorded perceived slant. Participants were screened for stereoacuity (>30 arcsec.) Results and discussion. (a) Individual differences were reliable and large, ranging from stereopsis having all the weight to having only moderate weight. For 4 observers data were close to the predicted stereo response function regardless of pattern. For the observers who showed an effect of conflicting perspective, horizontal lines (linear perspective) reduced perceived slant much more than vertical lines (foreshortening) with an intermediate effect for the grid. (b) Four observers showed this pattern of attenuation across stereo slants, while four only at greater stereo slants. Thus contrary to other studies, increasing conflict tended to reduce rather than increase the influence of stereo. (c) The fact that the two components of perspective compression, foreshortening and linear perspective, received very different weights, suggests that reported weightings in the literature of broadly-defined "cues" such as "texture" may lack generality. (d) Adding the two components of perspective via the grid pattern did not increase the weight given to perspective but the weight given to stereopsis. Even though the dotted lines all provided ample potential stereo information, configuration influenced stereo dominance. Thus stereo should not be regarded as a modular slant cue.

36.4022 Projectively inconsistent occluding contours have surprisingly little influence on SFM percepts

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Structure-from-motion (SFM) studies have shown that observers spontaneously perceive 3D structure in dot motion displays that are projectively consistent with a rigid 3D interpretation. However, observers can also perceive 3D structure in displays that are not projectively consistent with a 3D interpretation, such as the "rotating columns" display (Froyen et al., JOV 2013; Tanrikulu et al., VSS 2014, VSS 2015) in which 3D rotation is perceived in alternating image regions despite the constant-speed profile of the image motion. Even in standard SFM displays, the 3D percept is surprisingly robust to deviations of the dot speed profile from projective consistency (He et al., VSS 2015). Here, we extend the study of projective consistency to include the role of occluding contours. We manipulated (i) the degree of symmetry of the occluding contours; and (ii) the speed profile of the dots, varying it from perfectly constant speed to full cosine speed profile (projectively consistent with rigid rotation in depth). Critically, asymmetric contours are grossly inconsistent with a rotating 3D object, because an asymmetric object necessarily changes its silhouette as it rotates, but the contours in our displays do not. For each level of symmetry, we used the method of constant stimuli to obtain psychometric curves for proportion of "volumetric" responses as a function of the proportion of cosine motion. As expected, the proportion of "volumetric" responses increased monotonically with the proportion of cosine motion. However, the degree of shape symmetry had a surprisingly small effect. Although asymmetric displays required a slightly higher proportion of cosine motion to perceive volumetric structure, their psychometric curves were only slightly different than those for symmetric displays. The results show that projective consistency—even of occluding contours—plays a much less prominent role in the perceptual inference of 3D structure than in conventional SFM accounts.

36.4023 **Fast integration of depth from motion parallax and the effect of dynamic perspective cues** Vanessa Li[1](vanessa.li3@mail.mcgill.ca), Athena Buckthought[1], Curtis Baker[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

In everyday life, we perceive depth relationships in a scene seemingly effortlessly and almost instantaneously. However, past experimental studies on motion parallax and structure from motion have reported that integration times of 600-1000 msec are required for perception of depth or 3D structure. Here we re-examined the temporal characteristics of depth discrimination from motion parallax, using random dot textured surfaces. Relative shearing motions of textures were synchronized to the observer's head movements to portray a surface slanted about a horizontal axis. The dot displacements were produced under two different rendering schemes: orthographic and perspective. Perspective rendering differs from orthographic by including additional cues, i.e. variation of speed of the dots with distance, lateral speed gradients across the display and small vertical displacements. No pictorial depth cues or variation of the size of the random dots with distance were available, and thus the task was impossible without observer movement. Three observers performed a 2AFC depth discrimination task in which they reported the perceived direction of slant, and the presentation duration of the stimulus was varied over intervals ranging from 62.5 to 4000 msec. The stimuli were presented on a computer screen in a 28 degree diameter circular window, at 57 cm viewing distance. We found that 1) better performance occurred with perspective than orthographic rendering at all stimulus presentation durations giving above chance performance; 2) subjects were able to discriminate depth at durations as short as 125 msec; 3) performance for both types of rendering was relatively constant for durations over 500 msec, but dropped at shorter durations. Somewhat surprisingly, the integration of dynamic perspective cues does not seem to require additional processing time. Depth from motion parallax can occur much more rapidly than previously thought, consistent with the apparent swiftness of depth perception that is experienced in everyday life.

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36.4024 **Distortions of Perceived Metric Structure of a Symmetric Planar Object Rotating in Depth** Ying Yu[1](yu.1416@osu.edu), Alexander Petrov[1]; [1]Department of Psychology, Ohio State University

Psychophysical evidence indicates that, at viewing distances >60 cm, the perceived depth from binocular disparity significantly underestimates the true depth. One geometric consequence of this is that rigid objects should appear to change shape as they rotate in depth. To illustrate, consider a monitor such that 400 pixels subtend 10 cm along the vertical axis but only 8 cm along the horizontal axis. Suppose we draw a square (in pixels) and its two diagonals, and paint two of the resulting four triangles in white (like an upright hourglass) and the other two in black. Because of monitor distortion, this stimulus appears as a rectangle whose white sides are longer than the black. If this stimulus rotates 45 deg in the monitor plane, it appears as a rhombus rather than rectangle. After additional 45-deg rotation, it appears rectangular again, but now the black sides seem longer than the white. Method: 11 observers adjusted the width-to-height (W2H) ratio of a flat-panel monitor to make the stimulus described above appear as an exact square. Importantly, the observers could rotate the stimulus at will by turning a knob. The experimental manipulation was to rotate the monitor itself around its vertical axis so that the angle between the normal vector of the monitor and the line of sight was 0, 38, or 68 degrees, respectively. These viewing angles were counterbalanced across blocks within subjects. Binocular viewing from a chin rest, viewing distance 100 cm from stimulus center, 72 trials (=3 x 24) total. Results: The adjusted W2H ratio increased systematically as the viewing angle increased: mean W2H ratios = 1.04, 1.06, and 1.38. The precision across trials decreased: average standard deviations of the adjustments = 0.06, 0.09, and 0.17, respectively. This indicates a failure of shape constancy for a symmetrical object viewed under natural conditions.

36.4025 **Inhomogeneity of Perceived Slants With Different Motion-Based Visual Information** Xiaoye Wang[1](wang492@indiana.edu), Aaron Fath[1], Winona Snapp-Childs[1], Mats Lind[2], Geoffrey Bingham[1]; [1]Department of Psychological and Brain Science, Indiana University, Bloomington, IN, USA, [2]Department of Information Technology, Uppsala University, Uppsala, Sweden

Todd and colleagues (Todd et al., 2007; Todd, Christensen, & Guckes, 2010) reported a strong bias in perceived slant presented with static texture gradients with restricted viewing angle. People tend to underestimate the slant using texture when the viewing angle is small. The current study explored the similar distortion of perceived slant with different motion-based visual information. Methods We used random dot stereograms to display planar surfaces with 24 different slants (from 27° to 73° with 2° increment and 0° tilt) rotating around a vertical axis through the surface center, viewed under stereomotion, monocular structure-from-motion and texture, and combined visual information. Participants were instructed to adjust a line to match the slant of the surface. Results Judged slant error means and SDs were computed for each visual information condition and slant, and regressed onto actual slants. For all information conditions, error means were best fitted using concave downward quadratic trends, with maxima at 55° and intercepts with the x-axis at 40° and 70°. Judgments of slants between 27° and 40° overestimated and between 40° and 70° underestimated. SDs were also best fit by quadratics, but the peak occurred at the 40° intercept for the means with minima as slants approached 0° and 90°. Conclusion The current study extended the previous findings of bias in slant perception to different motion-related visual information. The results indicate that people tend to identify reference angles, where perceived slants were accurate and more precise. Mid-range slants were accurate but least precise. Bottom half of the range was underestimated and the top half overestimated.

36.4026 **Using the kinetic-depth effect to decouple convexity bias and face-specific knowledge in the hollow-face illusion** Attila Farkas[1](ajf215@ruccs.rutgers.edu), Thomas Papathomas[1,2], Steven Silverstein[3], John Papayanopoulos[4]; [1]Laboratory of Vision Research/Center for Cognitive Science, Rutgers University, [2]Department of Biomedical Engineering, Rutgers University, [3]Division of Schizophrenia Research, Rutgers University Behavioral HealthCare and Robert Wood Johnson Medical School Department of Psychiatry, Rutgers Biomedical and Health Sciences, [4]College of Engineering, Georgia Institute of Technology

Background: One of the best-known depth-inversion illusions (DII) that offers strong evidence for the influence of stored knowledge on the visual input [Bar et al. PNAS2006] is the hollow-face illusion [Gregory, "The intelligent eye", 1970; Georgeson, Perception 1979], where a concave face is misperceived as convex. A general explanation is that lifelong familiarity with convex faces overrides data-driven sensory signals. The convexity bias may also play a role in the illusion [Hill & Bruce, Perception 1994]. To isolate the role of the convexity bias we assessed the illusion strength using computer generated 3D convex and concave ovoid objects (results with similar computer generated face stimuli were reported last year [Farkas et al. VSS2015]). Methods: We modeled 14 ovoid "non-face" objects (7 convex, 7 concave), differing in shape, texture and depth structure. Three types of textures were mapped onto the objects, with random black-and-white square textels (texture elements): (1) "Concave texture": Textel size decreased linearly from periphery to center to provide perspective depth cue favoring concavity. (2) "Convex texture": Opposite size variation (increase from periphery to center), favoring convexity. (3) "Neutral texture": Uniform textel size. Each object oscillated around its vertical axis. Observers had to report whether the object was convex or concave. Results: The results indicate that DII strength depends on both structure and texture. The stimuli that produce the most ambiguous percept are the ones in which the textural depth cues compete against depth structure. Using this method we obtained a psychometric function for the DII tendency elicited by a set of virtual "non-face" objects. Conclusions - Discussion: The data show far weaker DII effects with ovoid stimuli as compared to the hollow-face illusion from our previous studies [Farkas et al. VSS2015]. These stimuli will be used to study differences in DII perception between schizophrenia patients and controls.

36.4027 **The perception of 3D shape from shading based entirely on transmitted light** Christopher Kallie[1](kallie.1@osu.edu), James Todd[1]; [1]Department of Psychology, Arts and Sciences, The Ohio State University

Traditional models for computing 3D shape from shading have focused on two physical processes that structure the pattern of luminance in an image: One based on Lambert's law that is applicable to matte surfaces, and another based on the law of reflection that is applicable to shiny surfaces. The present research was designed to investigate another possible process for structuring the pattern of light in an image based on Snell's law and the Fresnel equations that is applicable for transparent surfaces. The stimuli in this study consisted of crown glass objects with back lit illumination, so that there were no direct reflections toward the point of observation. Observers judged the 3D shapes of these objects along designated scan lines by adjusting spline curves to match the apparent profile of the surface in depth. The results revealed that these judgments were quite accurate except for a systematic underestimation of the depth profile. We have identified two possible sources of information that may be responsible for this high level of performance. Transmitted light has the greatest intensity when the outer boundary of a back lit surface faces away from the source of illumination, which is the opposite of Lambert's law. Another possible source of information arises from light that is refracted from one surface region, and then reflected from another toward the point of observation. This causes highlights along the sides of ridges and valleys, which accentuates those surface features. These findings suggest that the analysis of 3D shape from shading is much more complex than has typically been assumed by previous theoretical analyses.

Acknowledgement: NSF BCS-0962119

36.4028 **The effects of illumination on the perception of 3D shape from shading** Makaela Nartker[1](nartker.28@osu.edu), Christopher Kallie[1], James Todd[1]; [1]Department of Psychology, Arts and Sciences, The Ohio State University

A fundamental problem for the perception of 3D shape from shading is to achieve some level of constancy over variations in the pattern of illumination. The present research was designed to investigate how changes in the direction or manner of illumination influence the apparent shapes of surfaces. The stimuli included 3D objects with Lambertian reflectance functions that were illuminated by hemispheric dome lights, rectangular area lights, or point light sources. The directions of illumination were also systematically manipulated. All stimuli had exactly the same bounding contours so that those contours provided no information for distinguishing the different possible surfaces. Observers judged the 3D shapes of these surfaces by marking local depth minima and maxima along designated scan lines using a hand held mouse. The results revealed that the local depth extrema were shifted slightly toward the direction of illumination, but these changes were much smaller than what would be expected based on differences in the pattern of luminance among the stimulus images. These findings demonstrate that there is a substantial amount of illumination constancy in the perception of 3D shape from shading, but that it is not perfect. Several hypotheses are considered about how this constancy could potentially be achieved.

Acknowledgement: NSF BCS-0962119

36.4029 **Shape discrimination for 3D objects with conflicting stereo and shading cues** Jeffrey Saunders[1](jsaun@hku.hk), Young Lee[1]; [1]Department of Psychology, University of Hong Kong

We are able to discriminate the 3D shape of smooth volumetric objects from monocular information alone, using cues like shading and the boundary contour. With binocular viewing, stereo information has been shown to improve shape discrimination even when rich monocular cues are present. This study used cue conflict conditions to test the relative contributions of stereo and shading information to 3D shape perception. We generated binocular images for which the shape specified by shading in each eye's view was different from the shape specified by binocular disparities. Observers performed shape discrimination comparing these cue conflict stimuli to stimuli with consistent shading and stereo, or to stimuli that provided stereo information but no shading. We also measured the baseline discriminability of pairs of objects using consistent cue stimuli. Subjectively, the shading variations in cue conflict stimuli often appeared as variations in surface reflectance rather than solely effects of illumination. Despite this inconsistent percept, shading had a strong influence on shape discrimination. A pair of stimuli was more likely to be judged the same when shading information was consistent than when stereo information was consistent. Shading also influenced comparisons to shapes that were defined only by stereo. The results demonstrate that shading information has a strong influence on 3D shape discrimination even when conflicting stereo information is present, and when shading is not entirely attributed to illumination effects. We further found that the effect of shading depended on baseline discriminability: shading had more influence for pairs of objects that were difficult to discriminate than for pairs that were easy to discriminate. We speculate that stereo contributes a coarse estimate of 3D shape and shading is used to perceive finer shape variations.

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Motion: Mechanisms and psychophysics

Sunday, May 15, 2:45 - 6:45 pm

Poster Session, Pavilion

36.4030 **Motion discrimination is impaired when coarse and fine-scale patterns move together at the same speed** Raúl Luna[1](raluna01@estumail.ucm.es), Ignacio Serrano-Pedraza[1,2]; [1]Faculty of Psychology, Complutense University of Madrid, 28223, Spain, [2]Institute of Neuroscience, Newcastle University, NE2 4HH, UK

Motion direction discrimination at short durations is impaired when a static coarse-scale pattern is added to a moving fine-scale pattern. It has been suggested that this impairment is a consequence of an antagonism between motion-sensors tuned to fine and coarse scales (high and low spatial frequencies) (Serrano-Pedraza, Goddard & Derrington, Journal of Vision, 2007). However, when a static fine-scale pattern is added to a moving coarse scale pattern, motion discrimination is facilitated (Serrano-Pedraza, et al, Journal of Vision, 2013). In this study we wanted to test whether this impairment or facilitation occurs when both coarse- and fine-scales move together at the same speed. We measured duration thresholds for 7 participants using adaptive Bayesian staircases in a motion direction discrimination task. Two types of stimuli were used: simple drifting vertical-Gabor patches and complex vertical-Gabor patches resulting from the addition of two Gabor patches of different spatial frequencies. We tested for the simple Gabor patches: 0.25,0.75,1,1.5,2,3,6c/deg. For the complex stimuli we tested the following pairs of spatial frequencies: 0.25-0.75c/deg; 0.75-1.5c/deg; 1-3c/deg; and 2-6c/deg. The speed of the stimuli was always 2deg/sec, the contrast 0.275 and the size Sxy=2deg. Results for simple stimuli showed a reduction of duration thresholds as a function of the spatial frequency. Duration thresholds obtained with complex stimuli were, in all cases, similar to the duration thresholds of the component with the lower spatial-frequency of the pair. This suggests that motion discrimination was driven by the lower spatial-frequency component. However, in a second experiment, reducing the contrast of the lower spatial-frequency component also showed that duration thresholds for complex stimuli, in particular the pairs 0.75-1.5c/deg and 1-3c/deg, were higher than the duration thresholds obtained for each single component. These results are consistent with an inhibitory interaction between motion-sensors tuned to coarse and fine scales.

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36.4031 **First and second order transformational apparent motion have similar temporal dynamics** Kevin Hartstein[1](Kevin.C.Hartstein.GR@Dartmouth.edu), Peter Tse[1]; [1]Psychological and Brain Sciences, Dartmouth College

Introduction: Transformational apparent motion (TAM) occurs when one figure is replaced with another that overlaps the first in location, and is perceived as a shape change of the original object (Tse, Cavanagh, & Nakayama, 1998). This property reveals the importance of high-level figural processing constraints on motion perception that cannot be observed in standard apparent motion (Tse & Logothetis, 2002). Here, we seek to determine whether this figural processing effect persists in the absence of luminance-defined figures. Methods and Results: Our experiment compared the temporal characteristics of TAM for luminance-defined objects (black stimuli on a uniform gray background, first-order TAM) and texture-defined objects (white noise stimuli on a white noise background, second-order TAM). While maintaining fixation, participants viewed a TAM display consisting of two horizontally aligned squares in the lower visual field. At variable stimulus onset asynchronies, a rectangle appeared connecting the squares. At the

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same time, a cue-square appeared on top of one of the original stimuli, biasing the direction of perceived motion in the central rectangle toward that side. Participants indicated whether they perceived motion to the left, to the right, or no motion. Both first and second order TAM caused a compelling percept of motion in the cued direction (88.50% of trials in first-order, 77.65% in second-order). Although the figural information in second-order TAM is transient and relatively weak, the time course of second-order TAM was nearly identical to that of first-order TAM (see supplementary materials). This result suggests that even weak figural cues in the absence of luminance changes or first-order motion cues can strongly affect the perceptual interpretation of ambiguous motion. Conclusion: Here we show that weakly defined figures with no luminance differences guide motion perception with a time course similar to luminance-defined figural changes, emphasizing the importance of figural processing in motion perception.

36.4032 Frequency and temporal dynamics of motion pareidolia.

Nicolas Davidenko[1](ndaviden@ucsc.edu); [1]Psychology Department, UC Santa Cruz

We have previously shown that randomly refreshing textures presented at a constant frame rate give rise to illusory percepts of coherent apparent motion, a phenomenon we term motion pareidolia (Davidenko et al., VSS 2015, CogSci 2015). Here we report the effects of frame rate (Study 1) and number of frames (Study 2) on the strength of this phenomenon. Participants observed brief movie clips (between 0.625 and 10 seconds long) and classified each clip as vertical motion, horizontal motion, or random. Vertical motion clips consisted of a fixed random texture of 140x140 pixels alternately shifting up and down by 4 pixels, with 40% of pixels re-randomized at each frame (40% noise). Similarly, horizontal motion clips alternately shifted right and left with 40% noise, and random clips refreshed randomly at each frame (100% noise). Across studies, participants were very accurate at classifying vertical and horizontal motion trials (average proportion correct ~0.94), but very inaccurate at classifying random trials as random (average proportion correct ~0.57), replicating our previous motion pareidolia findings. In Study 1 (N=65), we found that whereas performance on motion trials increased monotonically as frame rate increased from 0.5Hz to 8Hz, performance on random trials showed a U-shape pattern, significantly dipping between 1Hz and 2Hz, suggesting that motion pareidolia peaks around this frequency. In Study 2 (N=85) we kept the frame rate constant at 2Hz and varied the movie clip durations from 3 to 9 frames. We predicted that as the number of frames increased, participants would accumulate more evidence for or against coherent motion, and performance would increase substantially, especially for random trials. Instead, performance on random trials stayed relatively constant, fluctuating between 0.60 and 0.65, across movie clip durations. Our results suggest that once illusory motion is perceived, it is likely to persist across many subsequent frame transitions.

36.4033 Internal vs. external determinants of human speed discrimination with natural image movies

Benjamin Chin[1](bechin@sas.upenn.edu), Johannes Burge[1]; [1]Department of Psychology, University of Pennsylvania

Accurate perception of motion depends critically on accurate estimation of retinal image motion. Recently, Burge & Geisler (2015) developed an ideal observer for retinal speed estimation based on the statistics of natural image movies and constraints imposed by the visual system's front-end. Psychophysical experiments with natural and artificial stimuli showed that this ideal observer tightly predicted the detailed shapes of a large set of psychometric functions. However, this previous work left unresolved whether the close match between human and ideal performance was driven by the properties of the natural stimuli, or whether it was due instead to spectacular coincidence. Here, we build upon traditional double-pass experimental methodologies to estimate the relative influence of internal noise and natural movie structure on human response variability. Five human observers viewed randomly-selected, contrast-fixed natural image movies in a 2IFC paradigm (1deg, 250ms). The task was to select the interval with the movie having the faster speed. In each pass of the experiment, psychometric functions were measured using the method of constant stimuli across a range of speeds (5 standard speeds x 7 levels/standard x 100 trials/level). Movies were never repeated within a pass. Each pass was identical. Eight passes were collected (28,000 trials). Human response agreement was computed for each comparison speed and compared to the response agreement of an ideal observer degraded by different amounts of internal noise. The pattern of human agreements is diagnostic of the importance of natural image variability; for example, responses would agree perfectly across repeats if image variability swamps internal noise. Our analysis shows that external factors have approximately as much impact as internal factors, and that the degraded ideal observer closely predicts the pattern of response agreement. Future work will examine the particular image movie properties that predict trial-by-trial performance.

36.4034 The double-drift illusion is isotropic across visual field locations and directions

Sirui Liu[1](sirui.liu.gr@dartmouth.edu), Patrick Cavanagh[1,2]; [1]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA, [2]Laboratoire Psychologie de la Perception, Université Paris Descartes, Paris, France

When the internal texture of a Gabor patch drifts in the orthogonal direction of the patch itself, the perceived path can deviate from its physical path by 45˚ or more (Tse & Hsieh, 2006; Lisi & Cavanagh, 2015). Recently, Adamian and Cavanagh (ECVP 2015) reported that the size of this double-drift illusion, when tested with an elliptical trajectory, is reduced when presented at either the vertical or horizontal meridian. In the present study, we used a Gabor patch that oscillated back and forth on a linear path, reversing its internal motion at the same time as the external motion reversed. We measured the strength of the illusion by asking subjects to add a physical tilt to the perceived path angle until the trajectory appeared to be aligned with two reference dots that were set at 45° from the initial motion axis. For a strong illusion, the path would already appear aligned with the dots and no additional physical tilt would have to be added. The weaker the illusion, the more physical tilt would have to be added to reach alignment. The physical path of the stimulus was centered at one of the eight isoeccentric peripheral locations (8˚ from fixation) with one of four external motion orientations (vertical, horizontal, right diagonal and left diagonal) and one of two adjusting directions (45° clockwise or counterclockwise from the initial physical path). In contrast to the previous finding, our results show that the magnitude of the motion-induced position shift of the double-drift stimulus was similar across all eight locations in the visual field for all the physical or the adjusted orientations of the motion path. Measured with a linear rather than curved path, the illusion appears to be based on its physical configuration and independent of retinal location or orientation at a given eccentricity.

36.4035 A Comparison of Radial and Rotational Plaid Speed Judgments

Nestor Matthews[1](matthewsn@denison.edu), Leslie Welch[2], Allison Murphy[1], Megan Puritz[1]; [1]Department of Psychology, Denison University, [2]Cognitive, Linguistic & Psychological Sciences, Brown University, [3]Department of Psychology, Denison University, [4]Department of Psychology, Denison University

Introduction: The Medial Superior Temporal (MST) region of the primate visual system responds to both radial and rotational motion (Duffy & Wurtz, 1991). These two motion types differ by 90 degrees in local motion vectors. Prior work suggests that when stimuli contain the combination of radial and rotational motion, participants can accurately estimate the individual vectors -revealing a local component decomposition (Barraza & Grzywacz, 2005). Despite this local component decomposition, random-dot radial motion studies have demonstrated distinct sensitivities (Xiao, Barborica & Ferrera, 2006) and developmental time-lines (Shirai, Kanazawa & Yamaguchi, 2006) for radial expansion versus radial contraction. No corresponding directional dependence occurs for dot-defined rotational motion. Here, we investigated whether plaid stimuli, like the previously reported dot stimuli, generate directionally dependent radial motion performance and directionally independent rotational motion performance. Method: Twenty-one Denison University undergraduates viewed displays containing two plaid stimuli, presented simultaneously to the left and right of a central fixation marker. On radial motion trials, one plaid either expanded or contracted at two octaves per second; the other did so 35 percent more slowly. On rotational motion trials, one plaid rotated either clockwise or anticlockwise at two revolutions per second; the other did so 20 percent more slowly. Participants reported which side contained faster motion. Results: Mean performance for radial expansion significantly exceeded that for radial contraction ($t(20)=2.263$, $p=0.035$, r-squared = 0.204), but the effect size was modest (78.5% versus 73.9% correct) and non-significant according to a sign test ($p=0.115$). Clockwise and anticlockwise motion generated statistically indistinguishable performance levels ($t(20)=0.860$, $p=0.40$, r-squared = 0.036). Conclusion: The small effect size generated by plaids with opposite radial directions seems surprising given the directionally dependent results in earlier studies that investigated radial judgments for dot patterns. This raises the possibility that distinct neural events may govern plaid-defined versus dot-defined radial judgments.

Sunday PM

36.4036 Illusory rotation and motion capture depend upon common fate factor among elements. Makoto Ichikawa[1](michikawa@chiba-u.jp), Yuko Masakura[2]; [1]Dept. of Psychology, Faculty of Letters, Chiba University, [2]Faculty of Media Theories and Production, Aichi Shukutoku University

When viewing the concentric circles, which consist of oblique components, the observers see illusory rotation of those circles by changing the viewing distance. 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 dots (Ichikawa et al, 2006, Perception, 35, 933-946). This illusory rotation of the superimposed dots is caused by "motion capture". We examined how motion signal with different directions in terms of apparent motion, as well as illusory motion signal from the oblique components, affects the motion capture. A CRT display presented dots with the inner and outer circles (14.3 and 17.2 deg in diameter) each that consisted of 72 oblique lines, which were tilted radially by 30 deg. We prepared four conditions. In the size change condition, the stimulus changed its size from 17.2 to 6.9 deg. In the rotation condition, the inner and outer circles rotated to opposite direction by 10.0 and 6.0 deg, respectively. In the rotation with size-change condition, the inner and outer circles, which consisted of 72 radial lines, rotated to opposite direction by 10.0 and 6.0 deg, respectively, and changed its size from 17.2 to 6.9 deg. In the rotation with translation condition, the inner and outer circles rotated to opposite direction by 10.0 and 6.0 deg, respectively, and the whole stimulus translated horizontally by 6.4 deg. Observers tended to perceive motion capture for the dots in the size change, rotation with size-change, and rotation with translation conditions. However, in the rotation condition, they tended to perceive induced motion for the dots. These results suggest that the existences of the common fate factor for the stimulus elements determine how to allocate and integrate the motion signal in each element in the stimulus to generate motion capture.

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36.4037 Rotating squares made out of drifting Gabors: the contributions of velocity and position based motion information to the perceived speed of a rotating object. Matthew Harrison[1](mt.harrison@gmail.com), Gennady Erlikhman[1], Gideon Caplovitz[1]; [1]Department of Psychology, University of Nevada Reno

A static Gabor patch containing a drifting sinusoidal grating appears to be displaced in the direction of the carrier motion. We introduce a novel 'rotating square' illusion in which drifting Gabor elements positioned to form a square, together give rise to a global rotational motion percept. This is accomplished by selecting the drift speed of each Gabor to match the component motion speed that would be expected for a physically rotating square. We use this stimulus to investigate the role of local 1st order 1D component motion in the representation of global rotational motion. In a series of psychophysical experiments we compare the perceived rotational speed of these illusory rotating squares to the speed of physically rotating squares across a variety of stimulus speeds and sizes. We find that across a range of rotational speeds < 24°/sec, when the squares were large so that individual elements fell in the periphery, the perceived illusory rotational velocity of the squares was equivalent to a physically rotating square with the same perpendicular motion components. This suggests that the pooling of local 1st order 1D component motion signals can fully account for the perceived speed of a rotating square. However, when the squares were smaller and elements were more centrally located, the perceived rotational velocity was slower in the illusory condition than for physically rotating squares. In this case, position-based motion information commonly associated with 2nd order motion (Seiffert & Cavanagh 1998,1999), contributes to the perceived rotational speed of a luminance-defined 1st order rotating square.

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36.4038 An anisotropic model of visual motion perception and perceptual learning Émilien Tlapale[1](emilien@tlapale.com), Barbara Dosher[1], Zhong-Lin Lu[2]; [1]Memory Attention and Perception Laboratory, Cognitive Sciences Department, University of California, Irvine, CA, USA, [2]Laboratory of Brain Processes, Department of Psychology, Ohio State University, Columbus, OH, USA

The performance on visual tasks involving stimuli oriented along the cardinal directions is significantly superior to the performance with the same stimuli oriented along oblique directions, a phenomenon classically designated as the "oblique effect" (Appelle 1972). Increased cell numbers or neural activity, and narrower tuning bandwidth for the cardinal directions have been suggested to account for the phenomenon (Li et al., 2003). Here we investigate the oblique effect in visual motion perception and perceptual learning by incorporating an anisotropy in the distribution of directional preferences of motion sensitive neurons into the integrated dynamical motion model (IDM) (Tlapale et al. 2014, 2015), a biologically plausible neural model including representations of several cortical areas (V1, MT, LIP) and their feedforward and lateral connections, with a novel neural mechanism for same-different decisions. Differential direction tuning bandwidths emerge as a direct consequence of the direction preference distributions. This biologically plausible model is more robust than previous static models of motion anisotropy (Rokem & Silver, 2009; Wong & Price, 2014). The anisotropic IDM correctly reproduces oblique effects in a range of representative experiments, including the classical visual motion perception experiments of Gros et al (1999), Matthews & Qian (1999) and Dakin et al (2005). Furthermore, the extended model accounts for the perceptual learning experiments of Ball & Sekuler (1982,1987), Watanabe et al (2001, 2002) and Liang et al (2015) through feedforward reweighting. It also generates predictions about the influence of aperture orientation on multi-stable motion displays. In summary, we developed a biologically plausible and robust dynamical neural model of visual motion perception and perceptual learning which includes neural dynamics of multiple stages of motion processing, precise descriptions of neuronal anisotropies and decision mechanisms, and is able to account for a large range of representative experiments from the literature on the oblique effect and perceptual learning.

Acknowledgement: This work was supported by the National Eye Institute Grant # EY–17491.

36.4039 Reverse-Phi Experiments Support the Counterchange Model of Motion Detection Harald Ruda[1](h.ruda@neu.edu), Guillaume Riesen[2], Howard Hock[3,4]; [1]Computational Vision Laboratory, Northeastern University, [2]Neurosciences Interdepartmental Program, School of Medicine, Stanford University, [3]Center for Complex Systems and Brain Sciences, Charles E. Schmidt College of Science, Florida Atlantic University, [4]Department of Psychology, Charles E. Schmidt College of Science, Florida Atlantic University

Previous experiments and modeling inspired by the counterchange (CC) model of motion detection (Hock, Gilroy & Harnett, 2002; Norman, Hock, & Schöner, 2014) have suggested further experiments using reverse-phi stimuli to discriminate between different motion models. Because they mix the responses of contrast detectors with different polarities (e.g., edge detectors with excitatory lobes on the left or right), the Enhanced Reichardt Detector (ERD) and motion energy detector predict reverse-phi motion will be perceived equally well for stimuli whose luminance polarity is inverted and stimuli that maintain the same luminance polarity during successive frames. On the other hand, the counterchange detector, which segregates the responses of contrast detectors with different polarities, signals reverse-phi motion only from chance correlations. We used reverse-phi square wave gratings (Chubb & Sperling's, 1988, Gamma stimuli) to eliminate chance correlations, and determine whether motion is signaled only by same-polarity edge detectors. Method. A grating was displaced to the left or right during successive frames, for a total duration of 1.0 sec. There were three different displacements, each smaller than the width of a single bar of the grating. Observers matched the perceived speed of an adjustable sine-wave grating to the square wave's perceived speed. Results. For gratings maintaining the same luminance polarity, perceived speed increased with increasing displacement (same duration for longer displacements). This result also was predicted by the ERD and motion energy models for gratings whose polarity inverted during successive frames, but the opposite was obtained. That is, perceived speed was greater for for the smaller displacements. This was because the distance over which motion was perceived in the reverse-phi direction was greater for same-polarity edge detectors than edge detectors with different polarities. Conclusion. Motion detection for the Gamma square wave stimulus is more likely determined by counterchange than ERD or motion energy detectors.

Acknowledgement: ONR (N00014-13-1-0092)

36.4040 The adaptive psiprdm method: optimizing psychophysical measurement using response times and accuracy. Nicolaas Prins[1](nprins@olemiss.edu), James Gaska[2], Marc Winterbottom[2]; [1]Department of Psychology, College of Liberal Arts, University of Mississippi, [2]US Air Force School of Aerospace Medicine, Wright Patterson AFB, Dayton, OH

The power-rate diffusion model (PRDM; Palmer, Huk, & Shadlen, J. Vis. 5(5): 1, 2005) relates both accuracy and mean response times (RTs) to stimulus strength in perceptual judgment tasks. The model assumes that perceptual evidence accumulates through a noisy diffusion process and that the average rate of accumulation of perceptual evidence scales with

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the stimulus intensity according to Stevens' power law. The model utilizes the information that is contained in the distribution of RTs allowing one to quantify an observer's sensitivity independent of the observer's standing on the speed-accuracy continuum. Here, we propose the adaptive psiprdm method which optimizes estimation of the four parameters of the PRDM by selecting, on each trial, the stimulus intensity that minimizes the expected entropy in the posterior distribution defined across the model's four parameters (cf. the psi method, Kontsevich & Tyler, Vis. Res., 39, 2729-2737, 1999). After each trial, the posterior distribution is updated based on both the accuracy and RT obtained on the trial. Unlike the original PRDM, in which likelihood functions are based on mean RTs, psiprdm utilizes likelihood functions based on the RTs for individual trials. The performance of the method was tested using simulations in which responses were generated by mimicking the diffusion process. Results indicate that the estimates of all of the model's four parameters are stable and virtually bias-free after approximately thirty trials. Furthermore, estimates of the observer's sensitivity parameter were found to be stable with respect to speed-accuracy trade-off manipulations. A comparison of the psiprdm method with a method that considers only the accuracy (not the RT) of responses indicates that while the former produces a bias-free estimate of the 'half-way accuracy' threshold in the psychometric function within about twenty trials, the latter typically requires hundreds of trials to do the same.

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36.4041 Position-based vs energy-based motion processing Rémy Allard[1](remy.allard@inserm.fr), Angelo Arleo[1]; [1]Sorbonne Universités, UPMC Univ Paris 06, INSERM, CNRS, Institut de la Vision

It is generally presumed that the perceived motion direction of an object is based on some integration of local motion signals extracted from energy-based motion detectors. However, objects are often perceived as moving in their veridical direction even when the direction of the mean local motion signal diverges from the veridical motion direction. Such percepts have been taken as evidence of complex motion integration of local motion signals to compute the veridical motion direction of objects. An alternative hypothesis is that the perceived direction of a moving object is not based on local motion signals at all, but rather based on tracking the position of the object. We evaluated the perceived motion direction of objects when the direction of the mean local motion signal diverged from the veridical motion direction (reverse-phi, furrow illusion and other stimuli). Energy-based processing of local motion signals and position-based tracking of the objects were each neutralized (or not) by manipulating inter-stimuli intervals (Smith, 1994) and crowding (Allard & Faubert, 2013), respectively. When both motion systems were neutralized, no motion direction was perceived. When only position-based tracking was neutralized, motion was perceived in the direction of the mean local motion signal, which suggests a simple integration (i.e., averaging) of local motion signals. When position-based tracking was not neutralized, objects were perceived as moving in their veridical direction whether energy-based motion processing was neutralized or not, which suggests that the perceived motion direction was determined by position-based tracking. We conclude that when position-based tracking of objects can operate efficiently, this strategy dominates and motion perception is not based on some integration of local (energy-based) motion signals. There is no need for complex integration of local motion signals to compute the veridical motion direction of objects.

Acknowledgement: This research was supported by ANR – Essilor SilverSight Chair

Perception and Action: Learning, feedback and neural basis

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4042 Utilizing interference to investigate a prediction model of visuomotor learning. Tony Wang[1](tony.wang@brown.edu), Nadira Yusif Rodriguez[2], Joo-Hyun Song[1,3]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University, Providence, RI, [2]Department of Psychology, University of Puerto Rico, San Juan, PR, [3]Brown Institute for Brain Sciences, Brown University, Providence, RI

Learning motor actions such pitching a baseball or kicking a football requires the person to update their motor system from sensory feedback. In order to understand the psychological mechanism of these actions, participants in the laboratory are trained to adapt to an artificial perturbation of the sensorimotor system. In the current experiment, participants completed a visuomotor adaptation task in which they learned to adjust their reach movement to account for a 45° perturbation between their movement and visual feedback. Visuomotor learning is thought to occur through an error-based mechanism in which participants adjust their reach movements by minimizing the difference between the predicted and actual visual feedback. The current study examined whether learning multiple reach movements (i.e., 15°, 30°, or 45°) affect learning rate and recall performance. Participants initially learned a small adaptation (15° or 30°), and in a second phase, participants learned a larger adaptation of up to 45°. According to the error-based model, multiple reach movements cannot be associated with the same visual stimulus as each new reach movement simply updates the prediction error. Alternatively, we hypothesized that learning different reach movements may engage separate encoding of each different motor action so that high similarity between motor memories may generate interference for new learning and recall. Consistent with our prediction, adaptation of 45° rotation was faster following the 15° rotation than 30° rotation. The findings suggest participants encode separate representations for each reach movement and this interferes with acquisition of highly similar reach movements

36.4043 Vision for guidance and vision for feedback: A study of throwing Abbey Deckard[1](adeckar1@swarthmore.edu), Luiza Santos[1], Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

Visually-directed throwing (i.e., throwing blindfolded after previewing a target location) is known to be more variable than visually-guided (normal) throwing. Here we explore the roles of visual guidance during the throwing action and of visual feedback gained by seeing the outcome of the throw. Varsity basketball players (Division III athletes: 8 F; 14 M) and other students (25 F; 17 M) performed 120 throws to a projected target from a distance of 4 m. LCD shutter goggles were used to block vision either immediately after the release of the ball (allowing visual guidance, but denying feedback) or during the period leading up to the release (denying visual guidance, but allowing visual feedback). Alternating blocks of 10 trials in each condition were used, with the first 40 trials excluded as practice. Both aim (deviations left and right) and distance calibration (deviations in depth) were analyzed for the remaining 40 trials in each condition. Athletes had better aim (lower variance in performance) with visual guidance than with visual feedback, $t(21) = 5.04$, $p < .001$ but non-athletes showed no differences in aim between the two conditions and were worse overall than the athletes. Both athletes and non-athletes tended to slightly underthrow with feedback, but tended to show improvement over the course of each set of 10 feedback trials. However, both groups seemed to overcompensate when feedback was withdrawn, overthrowing by several centimeters on average. We conclude that both visual guidance and visual feedback are important factors in the control of throwing, with guidance primarily providing stabilization of aim in skilled throwers, and visual feedback providing force calibration.

Acknowledgement: NEI R15 EY021026

36.4044 Dynamic visual feedback is sufficient to improve drawing Judith Fan[1](jefan@princeton.edu), Daniel Yamins[2], Nicholas Turk-Browne[1]; [1]Department of Psychology, Princeton University, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology

Drawing is a powerful tool for communicating ideas — a few well-placed strokes can convey the identity of a face, object, or scene. How do people learn to produce recognizable drawings? In a previous study, we examined how drawing objects in an online game influenced how well these objects could be drawn later. Performance was quantified using a multi-way classifier trained on output from a high-performing, deep convolutional neural network model of ventral visual cortex. After training, participants produced drawings that were better recognized by the model, owing to differentiation between representations of objects in the model. Here we examine which aspects of the training procedure account for this improvement. One possibility is that repeated visual exposure to drawn images may be sufficient to improve performance. To test this, we recruited 593 naïve participants who were each uniquely matched to a participant in the original cohort. They repeated the same procedure of drawing before and after training, except that instead of drawing during training, they viewed the final sketch produced by their matched participant. They did not significantly improve, despite receiving identical visual exposure — if not enhanced exposure (they only viewed completed drawings). Another possibility is that the dynamic visual feedback generated while constructing drawings was responsible for the improvement. To test this, we repeated

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the experiment with a new cohort of 593 participants who watched video replays of each drawing being produced, stroke-by-stroke, by their matched participant. These participants did significantly improve on the drawing task, though to a lesser degree than the original cohort. Dynamic visual feedback did not fully reproduce the original results, however, as performance on related but unexposed objects was not reliably impaired. These studies suggest that observing the dynamic process of drawing construction plays a specific role in enhancing visual production skill.

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36.4045 Masked Priming: The Roles of RT Carry-Over and Congruence Sequence Effects Ulrich Ansorge[1](ulrich.ansorge@univie.ac.at), Christoph Huber-Huber[1]; [1]Faculty of Psychology, University of Vienna

We tested the influences of response time (RT) in a preceding trial n-1 for masked primes' congruence effects in a following trial n. Relative to masked incongruent primes, masked congruent primes facilitate responding to visible targets ('congruence effect'), even where masking prevents prime visibility. Importantly, studies showed congruence sequence effects with masked primes: stronger congruence effects in n following congruent n-1 than incongruent n-1 trials. Here, we asked whether the congruence sequence effect could be driven by intertrial carry-over of RTs and whether awareness of response speed could be a critical factor. Employing a linear mixed model approach with masked word primes and visible word targets, we found a congruence effect and stronger RT carry-over for congruent than for incongruent trials but no evidence of a congruence sequence effect (Experiment 1). In contrast, using arrows as masked primes and visible targets led to congruence and congruence sequence effects with masked primes (Experiments 2 and 3). In addition, a critical role of RT carry-over was replicated, but congruence sequence effects were not entirely explained by RT carry-over effects. Critically, in Experiments 1 and 2, RT carry-over was independent of the participants' awareness of their response speed. Similarly, the participants' awareness of the primes was not critical for their congruence sequence effects (Experiments 1 to 3). Jointly, results showed that congruence sequence effects in masked priming experiments depend on intertrial RT effects, but carry-over of RTs can only partially account for congruence sequence effects.

36.4046 A comparative study of common coding for observed and executed actions in human and non-human primates. Prosper Agbesi Fiave[1](prosperagbesi.fiave@kuleuven.be), Jan Jastorff[2], Koen Nelissen[1]; [1]Lab for Neuro- & Psychophysiology, KU Leuven Medical School, Leuven, Belgium, [2]Research Group Psychiatry, KU Leuven, Leuven, Belgium

Numerous electrophysiology studies have shown the presence of mirror neurons throughout the macaque brain. Given that invasive human single cell data is scarcely available, the existence or absence of mirror neurons in the human brain has been inferred through indirect techniques like fMRI, where techniques like repetition suppression (RS) and multivariate pattern analysis (MVPA) have been suggested as tools to uncover the human mirror neuron system. Nevertheless, it has not been shown that MVPA analyses would suffice to reliably identify mirror neuron areas in the monkey. To investigate the potential of MVPA analyses to demonstrate common coding, we performed a comparative fMRI study in humans and macaques. Subjects either observed or executed reaching or grasping actions in a 3T scanner. Using both univariate and MVPA techniques, we investigated common coding for observed and executed actions at the whole brain level and in specific regions-of-interest. Our main focus was on investigating whether known monkey mirror neuron areas would allow successful cross-modal decoding. Univariate analyses yielded overlapping responses for observed and executed actions in parietal and frontal regions in both species. Unimodal decoding (separate for visual and motor domain) demonstrated action specificity in numerous brain regions, including visual, parietal, somatosensory, premotor and primary motor regions in humans and monkeys. Cross-modal decoding however, yielded asymmetric results in both species, showing significant decoding in a subset of regions only when going from visual to motor domain (training on visual, testing on motor data). Likewise, a region-of interest analysis of specific monkey brain regions known to house mirror neurons (F5, F1, AIP, PFG) only found unimodal or unidirectional cross-modal (visual to motor) evidence of action specificity and common coding. These data suggest that asymmetric cross-modal fMRI decoding results do not warrant strong claims about the presence of mirror neurons in the brain.

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36.4047 Do dorsolateral and dorsomedial pathways interact? Investigating parieto-frontal connectivity during a prehension task: a TMS-fMRI study. Giulia Malfatti[1](malfatti.giulia@gmail.com), Simona Monaco[1], Guido Barchiesi[1], Luigi Cattaneo[1], Luca Turella[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

The neural substrates subtending prehension, our ability to reach and grasp objects, comprise two parieto-frontal pathways. The dorsomedial pathway connects the occipito-parietal cortex (superior parieto-occipital cortex, SPOC, and superior parietal lobule, SPL) to the frontal lobe (dorsal premotor area, PMd), while the dorsolateral pathway connects the inferior part of the parietal lobe (anterior intraparietal sulcus, aIPS) with the ventral portion of the precentral gyrus (ventral premotor area, PMv). Both pathways are involved in the planning and execution phase of hand actions, however it is yet unknown whether and how information is transferred within and between these pathways. To answer this question, we adopted a combined approach involving offline 1 Hz repetitive Transcranial Magnetic Stimulation (rTMS) and functional Magnetic Resonance Imaging (fMRI). This approach allows identifying the connectivity profiles in normal conditions and causal modifications induced by offline rTMS. Participants (N=13) performed a grasping movement towards an object while lying in the MR scanner. We manipulated presence or absence of visual feedback and TMS stimulation. We asked participants to keep their eyes either closed (No visual feedback) or open (Visual feedback) when planning and executing the action. Participants performed these tasks after offline 1 Hz rTMS stimulation (Stimulation) or after sham stimulation over the same site (No Stimulation). Offline rTMS was applied over left SPOC as this area is a crucial hub for the fronto-parietal network. Our results showed task-related modulations of connectivity following sham stimulation, suggesting the interplay within and between regions of the two pathways. Furthermore, TMS perturbation over SPOC induced modifications in these connectivity profiles supporting the existence of specific causal interactions between different fronto-parietal regions. Overall, our results suggest that perturbation of one hub of this cortical network induces widespread modifications in both pathways.

36.4048 Target localization errors across the visual field of humans with long-standing V1 damage Elizabeth Saionz[1,2,4,5](elizabeth_saionz@urmc.rochester.edu), Matthew Cavanaugh[3,4,5], Adin Reisner[5], Krystel Huxlin[4,5]; [1]Translational Biomedical Science Program, [2]Medical Scientist Training Program, [3]Neuroscience Graduate Program, [4]Flaum Eye Institute, [5]University of Rochester

Subjects with unilateral cortical blindness (CB) report difficulties reading, navigating, and recognizing shapes despite normal visual processing in at least one visual hemifield and intact eye movements. Dilks and colleagues (2007) reported shape distortion across the blind field border in one quadrantanope, prompting us to ask if this could represent a more generalized phenomenon. To begin answering this question, we assessed target localization in 6 CB subjects. A Gabor patch (3° diameter) was presented on a touchscreen at one of 121 eccentric locations, followed by a full-screen mask. Subjects were instructed to touch the screen where the target had been presented. There were five repetitions per target location. The task was completed using static (spatial frequency [SF]: 1 cpd, temporal frequency [TF]: 0 Hz) or drifting (SF: 1 cpd, TF: 10 Hz) Gabors. Four of the CB subjects repeated the task after one year of global direction discrimination training (see Huxlin et al., 2009; Das et al., 2014). Localization accuracy was computed as the mean difference between the five touch responses and target location; reliability was computed as the standard error of that mean. Humphrey perimetry was performed to map areas of reduced luminance sensitivity (LS) in each CB subject. Compared to intact regions of the Humphrey visual field (LS ≥25 dB), CB subjects were less accurate and reliable in deeply blind regions (LS ≤3 dB), but displayed comparable accuracy and reliability in intermediate regions (LS=3-25 dB). Target type (static vs. drifting) had no effect on accuracy or reliability. Quadrantanopes maintained a general ability to distinguish upper from lower, and central from more peripheral targets in their blind field; hemianopes did not. Finally, visual discrimination training, which improved performance in CB fields, also reduced mean localization error, suggesting that discrimination training improves utilization of location information in cortically blind fields.

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36.4049 **Perceptual and Motor Effects of Letter Writing on Brain Regions Associated with Letter Perception**
Sophia Vinci-Booher[1](s-vincibo@indiana.edu), Neha Sehgal[1], Felipe Munoz-Rubke[1], Karin James[1]; [1]Indiana University

Visual perception of individual letters recruits fusiform gyri(FG), parietal cortex(PC), and frontal cortex(FC); however, letter-selective responses are often associated with the L-FG. All of these regions respond most strongly for letterforms with which the observer has experience hand-printing. Therefore, letter perception responses should be similar to letter printing responses and sensitive to the motor component of letter printing. During fMRI scanning, 6 literate adults hand-printed letters and shapes with and without ink, perceived dynamic re-presentations of their own hand-printed letters and shapes, perceived typeface letters and shapes, and pencil-tapped on an fMRI-compatible tablet.[1]Contrast maps were created from SPMs from random effects GLMs. Contrasting hand-printing letters over shapes with ink and perceiving re-presented letters over shapes indicated that L-FG, L-PC, and L-FC responded most strongly to the perceptual component of letter printing($p_{voxel} < .01$;$p_{cluster} < .001$). Contrasting hand-printing letters over shapes with ink and hand-printing letters over shapes without ink indicated that L-FG and R-PC responded most strongly to the motor component($p_{voxel} < .01$;$p_{cluster} < .001$).[2]ROIs were defined in L-FG and R-FG by contrasting perceiving typeface letters and shapes. Comparing hand-printing forms with ink and hand-printing forms without ink revealed non-form-selective effects of the perceptual component in L-FG($t_w(11)=9.76, p < .001$) and R-FG($t_w(11)=6.56, p < .001$). Comparing hand-printing forms with ink and perceiving re-presentations revealed significant non-form-selective effects of the motor component in L-FG($t_w(11)=4.33, p < .01$) and R-FG($t_w(11)=5.48, p < .001$). Comparing hand-printing letters over shapes with ink and perceiving re-presented letters over shapes revealed a significant letter-selective effect of motor in only the L-FG($t_w(5)=2.80, p < .05$), which is intriguing given that the R-FG responded stronger than the L-FG overall($t_w(58)=8.30, p < .001$). Comparing hand-printing forms with no ink and pencil-tapping did not reach significance in either ROI. Results suggest that letter perception and printing are supported by similar neural systems and that the L-FG is strongly associated with visually-guided actions with letters.

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36.4050 **Disentangling aspects of vision-guided motor coordination with pupillometry and choline supplementation**
Marnix Naber[1,2,3](marnixnaber@gmail.com), Peter Murphy[2,3,4], Bernhard Hommel[2,3], Lorenza Colzato[2,3]; [1]Helmholtz Institute, Utrecht University, [2]Experimental Psychology, Leiden University, [3]Leiden Institute for Brain and Cognition, Leiden University, [4]Department of Neurophysiology, University Medical Center Hamburg

Vision is not passive. One role of vision is to guide action for effective interaction with the environment. However, the mechanisms influencing visuomotor performance are poorly understood. In the current study we investigated whether visuomotor performance can be altered by choline supplementation in healthy human participants. As a proxy of cholinergic activity, participant's pupil size was measured at fixed intervals after the ingestion of 2 grams choline or placebo. Seventy-five minutes after ingestion participants were tested on their accuracy and speed of computer mouse movements in a visuomotor coordination task. We found that their pupil constricted after choline administration and that their movements became more accurate but slower. Further, the amount of pupil constriction per individual predicted the improvement in accuracy. In a second experiment we investigated more closely the link between pupil size and vision-guided correction movements as a function of time. We found that pupil dynamics highlight the phases and extent to which the precision of motor responses is improved through visual feedback. These findings suggest that cholinergic activity, as manipulated with choline and probed with pupil constrictions, is linked to the speed-accuracy trade-off. We suggest that cholinergic networks in the nervous system play a central role in the coordination of actions towards visual stimuli and that pupillometry is a promising method to assess the speed-accuracy trade-off and cholinergic activity.

Attention: Features and objects

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4051 **Feature-based attentional influences on the accommodation response**
Hamed Bahmani[1](hamed.bahmani@uni-tuebingen.de), Wolfgang Fuhl[2], Esteban Gutierrez [2], Enkelejda Kasneci[2], Siegfried Wahl[1]; [1]Institute for Ophthalmic Research, University of Tuebingen, Roentgenweg 11, 72076 Tuebingen, Germany, [2]Department of Computer Engineering, University of Tuebingen, Sand 13, 72076 Tuebingen, Germany

Accommodation is known as the process by which the vertebrate eye changes optical power to maintain focus on an object as its distance varies. This process is considered as an oculomotor reflex which is controlled by the Edinger-Westphal nucleus. Afferent limb of the neural circuit of accommodation also involves the visual association cortex which is responsible for complex visual processing. It has been shown that visual imagery and concurrent mental activity can modulate accommodative response. In the present study, we investigate possible effects of covert attention on accommodation response. We tested the hypothesis that covertly attending to a moving object could modulate accommodation. We used an autorefractor in a custom made setup to measure the accommodation of the human eyes. The subjects have been instructed to fixate on the center of the infrared camera, while attending to a linearly moving target in their peripheral visual field. They were asked to report the position of the target by pushing a button when it crossed certain markers. We found that the accommodation was significantly altered from the baseline at the moments of focused attention, although there was no displacement of the fixation point. We confirmed that the subjects have not made saccades to the moving target by analyzing the gaze direction. It has been shown extensively that higher cognitive functions of the brain such as visual attention could change the pupil size and dynamics. We provided further evidence that attentional state is reflected in the accommodative response. These findings could shed light on the mechanisms and neural circuits of accommodation and oculomotor system. Moreover, our finding could provide a new behavioral tool to monitor attentional state when pupil dynamics are not reliable. Next steps in this study would be measuring different feature-based attentional effects on multiple accommodative states of the eye.

36.4052 **Complex Attention Filters for Low Contrast Items**
Howard Yang[1](howary1@uci.edu), Peng Sun[2], Charles Chubb[3], George Sperling[4]; [1]University of California, Irvine

Drew et al. (JOV 2010) found that in estimating the centroid (center-of-gravity) of a random cloud of dots varying in grayscale, observers can give approximately equal attentional weight to all dots. Yang, Sun, Chubb, & Sperling (VSS 2013) found observers can estimate centroids giving weight proportional to contrast magnitude to all dots as well as just the light (dark) dots, ignoring dark (light) dots. Here we ask whether observers can weight dots in inverse proportion to contrast magnitude. Method. Stimuli were random dot clouds comprising 8 or 16 dots varying in Weber contrast. In a given attention condition, the observer strove to mouse-click the centroid of the dot-cloud, weighting dots in accordance with a specified target filter defined by (1) a target-dot set and (2) a weighting rule. There were three target-dot sets: All-dots, Dark-only (dots darker than the background), Light-only (dots lighter than the background). There were also three weighting rules: weight target dots equally (E-weight), in proportion to contrast magnitude (P-weight), or in inverse proportion to contrast magnitude (I-weight). (All involved giving weight 0 to non-target dots.) Results. Performance in the E-weight and P-weight conditions revealed high efficiency and filter accuracy. Attention filters achieved in the I-weight conditions differed strikingly from those achieved in the E and P-weight conditions. In particular, for single polarity Dark-only and Light-only target sets, the attention filters achieved in the I-weight condition matched the target filter well, and performance was moderately efficient. Strikingly, for Dark/Light-only targets with both polarities, observers were able to filter out non-target dots nearly perfectly. Performance was worse for the All-dots target set (Os had difficulty achieving attention filters that matched the target filter, and efficiency was lower). Conclusion. Os can achieve efficient attention filters selective for a single contrast polarity that weight dots in inverse proportion to contrast magnitude.

36.4053 **Feature Redundancy Benefits in Different Attentional Modes**
Christine Nothelfer[1](cnothelfer@gmail.com), Steven Franconeri[1]; [1]Northwestern University

Feature-based attention is critical for exploring both real-world and artificial displays. Prior work (Nothelfer & Franconeri, VSS 2014) shows a substantial benefit for selection of redundant dimensions (color and shape) that specify a set, relative to selection of either dimension alone. We tested whether this redundancy benefit depends on attentional mode - global versus serial search - and whether it leads to response time differences when viewing realistic displays. Objects were grouped in each quadrant of the screen, with targets forming a partial ring across three quadrants, embedded among distractors. In one block (global task), participants indicated toward which quadrant the ring's gap was angled ('ring' trials). Another block (serial task) contained these same 'ring' trials, but also similar 'mixed' trials in which objects from two target-containing quadrants were randomly placed so as to no longer form a target ring, encouraging a serial attentional mode. Participants indicated which quadrant lacked targets. In both blocks, participants quickly pressed the spacebar upon knowing the answer, after which a mask appeared and participants indicated the specific quadrant. Targets (e.g., blue asterisks) were identical to each other within a trial, and differed from distractors in color only (color trials), shape only (shape trials), or both color and shape (redundant trials). Examining only 'ring' trials, we found that redundant feature-selection benefited (40ms) compared to the faster of the single dimensions (color or shape trials) per participant. This did not change depending on attentional mode. Selection of redundant dimensions appears to speed both global and serial selection of a set of objects. This finding has implications for feature encoding guidelines for data visualization (e.g., when graphing software such as Microsoft Excel defaults to redundant shape/color glyphs) for a range of tasks (e.g., judging the shape of a data point set versus searching for outlier points).

36.4054 **Relational or optimal tuning of visual attention** Josef Schönhammer[1](josef.schoenhammer@unige.ch), Dirk Kerzel[1], Stefanie Becker[2]; [1]Université de Genève, [2]The University of Queensland

In visual search, the tuning of attention depends not only on the target feature but also on the nontarget ("context") features. How do target and nontarget features interact? The relational theory proposes that when target and nontarget features remain fixed, attention is tuned to relative feature properties (Becker, 2010). In Experiment 1, we sought evidence for the theory using previously untested colors. For example, the target was greenish-yellow and the nontargets yellow. Following the theory, attention should be tuned to "greener". In line with the theory, spatially unpredictive precues captured attention only when they were greener than the context. For instance, a green cue in a greenish-yellow context captured attention, as evidenced by spatial cueing effects on response times. Simultaneously, a greenish-yellow cue in a green context (yellower) did not capture although it shared the target feature. However, target and nontarget colors were very similar. Thus, attention might not have been tuned to relative attributes, but to exaggerated feature values to improve internal target-nontarget discrimination (e.g., Navalpakkam & Itti, 2007). For example, when the target was greenish-yellow and the nontargets yellow, attention might have been tuned to green instead of greener. Following such an alternative account, attention should not be tuned to exaggerated features when target and nontargets are dissimilar, but to the exact target feature. In Experiment 2, the target was again greenish-yellow but the nontargets were red, for example, which are highly dissimilar colors. The cues were the same as in Experiment 1. In line with the relational theory, cues only captured attention when they had the same relative attribute as the target, independently of whether they had the exact same color as the target. The results indicate that attention can be tuned to the relative target-nontarget attributes even when target and nontargets are relatively easy to discriminate.

36.4055 **Distractor probability modulates tuning of target representations.** Joy Geng[1,2](jgeng@ucdavis.edu), Nicholas DiQuattro[1,2]; [1]Department of Psychology, University of California Davis, [2]Center for Mind and Brain, University of California Davis

Theories of feature-based attention postulate gain modulation of sensory neurons that encode target features to enhance processing of task-relevant information (e.g., Treue and Martinez-Trujillo, 1999). More recently, Navalpakkam and Itti (2007) demonstrated that target representations are also shifted to optimize the distinctiveness of targets to distractors (see also Becker et al., 2010). For example, orange targets may be represented as being more "reddish" if distractors are predictably "yellowish". However, it remains unclear whether shifting target representations away from distractor features is the only way to reduce distractor interference. We examined this question in 3 experiments (each N=40) using a visual search task. A target defined by a single color was presented with a single distractor that differed from the target-color by 0 to 60 degrees in L*a*b color space (5 degree increments). The probability of "high-similarity" vs. "low-similarity" distractors was manipulated between-groups by determining their presentation frequency from a mirror-reversed half-normal distribution. The group with a greater probability of seeing high-similarity distractors had shorter RTs and higher accuracy, but only for highly similar distractors. Importantly, in a simultaneous target identification task, both groups showed a similar shift in representing the target hue as being more distant from the distractor set (i.e., counter-clockwise from the target color). However, subjects in the high-similarity group were also less likely to identify as targets colors that were used as highly similar distractors. This suggests that being exposed to more similar distractors produced asymmetrically "sharper" target tuning. In sum, these experiments suggest that the target representation is always shifted to optimize distinctiveness from the distractor set, but that increased exposure to highly similar distractors further sharpens the target representation to more effectively suppress highly similar distractors.

Acknowledgement: NSF

36.4056 **SSVEP captures predictive feature-based attentional tuning for point-light biological walker detection in unattended spatial locations** Rakibul Hasan[1](hasanr@uci.edu), Ramesh Srinivasan[1,2], Emily Grossman[1]; [1]Department of Cognitive Sciences, School of Social Sciences, University of California, Irvine, [2]Department of Biomedical Engineering, Henry Samueli School of Engineering, University of California, Irvine

Introduction: Feature-based attention boosts the gain of neurons tuned to task-relevant features, even for matched features in unattended locations. Thus, feature-selectivity in unattended regions carries information about attended features, and this can be measured through frequency tagging of the unattended region (steady state visually evoked potentials, or SSVEP; Bridwell et al. 2012; Painter et al., 2014). In this study, we measure the feature-selectivity of anticipatory SSVEPs during a detection task to test whether neural signals for attentional filtering predict behavioral performance. Methods: Subjects monitored for the presence of a point-light human walker embedded in uniform random dynamic noise in the center of the screen (a detection task in the attended region). The target was surrounded by peripheral annulus with 100% coherent noise moving left, right, up or diagonal, and flickering at 15 Hz (the SSVEP-tagged unattended region). To measure attentional (not perceptual) modulations of the SSVEP, we analyzed only the EEG data collected 1 second before the onset of the target. We computed tuning curves (normalized SSVEP power) from this pre-target interval using the electrodes with highest SSVEP power. A Partial Least Squares regression model determined the extent to which cortical coherence maps generated with those electrodes as seeds predict individual participant's d-prime sensitivity. Results: The highest SSVEP power electrodes over posterior parietal cortex (PPC) were modulated by the direction of the unattended feature, strongest on trials in which the unattended motion matched the dominant local motion of the "backstroke" of the feet. Coherence between PPC and dorsolateral prefrontal cortex on those same trials successfully predicted individual participant's d-prime sensitivity. Participants with higher d-prime values had higher coherence, and vice versa. Conclusion: The results from this experiment demonstrate importance of the backstroke of the feet as a cue for detecting bipedal motion of humans, and attention to that feature predicts subsequent perceptual sensitivity.

36.4057 **Visual features for perception, attention, and working memory: Toward a three-factor framework** Liqiang Huang[1](lqhuang@psy.cuhk.edu.hk); [1]The Chinese University of Hong Kong

Introduction: Visual features are the general building blocks for attention, perception, and working memory. But it remains largely unknown whether they work interchangeably in various tasks. For example, could it be possible that colors work especially well in visual search, but bar orientations work especially well in change detection? Or are they always "general" for all tasks? Here, I explore the factors which can quantitatively predict all the differences they make in various paradigms. Method: I tried to combine the strengths of experimental and correlational approaches in a novel way by developing an individual-item differences analysis which reveals the relations between the ways in which an item is processed in multiple tasks. To reflect the wide range of the visual features and the tasks they are used in, I included 16 stimulus types and 8 tasks. A large sample size (410) ensured that all eight tasks had a reliability (Cronbach's α) of no less than 0.975, allowing the factors to be precisely determined. Results: Three orthogonal factors were identified which correspond respectively to featural strength (i.e., how close a stimulus is to a basic feature), visual strength (i.e., visual quality of the stimulus), and spatial strength (i.e., how well a stimulus can be represented as a spatial structure). Featural strength helped substantially in all the tasks but moderately less so in perceptual discrimination; visual strength

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helped substantially in low-level tasks but not in high-level tasks; and spatial strength helped change detection but hindered ensemble matching and visual search. Conclusion: Jointly, these three factors explained 96.4% of all the variances of the eight tasks, making it clear that they account for almost everything about the roles of these 16 stimulus types in these eight tasks.

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36.4058 Tuning perception: the content of visual working memory biases the quality of visual awareness Christine Salahub[1](cs13aj@brocku.ca), Stephen Emrich[2]; [1]Psychology, Brock University, [2]Psychology, Brock University

The likelihood that an individual will become subjectively aware of a visual stimulus can be affected by experimental manipulations of the stimulus itself (i.e., visual masking) or manipulation of cognitive factors. For example, previous studies have demonstrated that items held in visual working memory (VWM) that match target features allow targets to reach visual awareness faster. These studies on visual awareness have often used coarse measures of awareness, such as present/absent or forced-choice judgments. This has resulted in an all-or-none conceptualization of visual awareness, wherein an item is either seen or remains "invisible". However, recent evidence from object-substitution masking paradigms (OSM) suggest that visual awareness may instead be a graded process, as masking an item decreases the quality of its perceptual representation in addition to its threshold of awareness. In the present study we examined whether items held in VWM could influence the quality with which a partially masked target reached awareness. Participants were asked to hold an oriented Landolt C in VWM across each OSM trial (set size 2 or 4). On half of the trials the orientation of the Landolt C held in VWM matched the masked target, and on the other half it did not match the target. Data were analyzed using the three-component mixture model to determine the proportion of target responses, guesses, non-target responses, and the error (standard deviation) of responses within each condition. It was found that targets matching the contents of VWM were subsequently perceived with greater precision (i.e., less error). The item held in VWM did not affect the likelihood of making a target response, guess, or non-target error. These results suggest that items held in VWM are able to tune the quality of visual representations, which is a finding that is at odds with an all-or-none conceptualization of consciousness.

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36.4059 Perceptual completion alters the cortical level at which object-based attentional selection is evident Shahd Al-Janabi[1](al-janabs@uwm.edu), Nofar Strommer-Davidovich[2], Shai Gabay[2], Adam Greenberg[1]; [1]Department of Psychology, College of Letters and Sciences, University of Wisconsin-Milwaukee, [2]University of Haifa, Israel

It remains unknown whether attention selects information 'early' or 'late' in the information-processing stream. Object-based attention (OBA) is well-positioned to shed light on this long-standing debate given that some studies have reported OBA effects even when object percepts are incomplete, suggesting that perceptual object formation happens prior to OBA deployment (though, most data suggest a later selection). Here, we aimed to ascertain the level within the visual cortical hierarchy (V1-V4, etc.) at which effects of OBA are first observed. While acquiring fMRI data, we asked participants to identify a target that was preceded by a central arrow cue (60% valid) in the double-rectangle paradigm (cf. Egly et al, 1994). The rectangles were either occluded or visible (un-occluded). Behaviorally, participants identified the target faster when it appeared on the cued object versus the uncued object. This same-object advantage emerged irrespective of object occlusion. We independently localized retinotopically-specific regions of cortex corresponding to target locations (object ends) to examine neural fluctuations in each region of the visual cortical hierarchy (both dorsal and ventral aspects). Consistent with our behavioral data, following target onset, activation in early visual areas increased at locations on the cued object, but not the uncued object; indicative of a neural same-object advantage in these regions. Specifically, we found that cue-evoked OBA effects are not evident in V1, emerging in V2 and V3, whereas target-evoked OBA effects are strongest in V1, but weaken in V2 and V3. Our results also indicate that cue-evoked object-based effects differ between the visible and occluded conditions, suggesting that object selection may vary along the visual cortical hierarchy. Thus, the level of the visual cortical hierarchy at which effects of OBA are observed may be flexible (early vs. late), depending on whether the target of selection (here, an object) comprises a completed percept.

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36.4060 Seeing stability: Intuitive physics automatically guides selective attention Chaz Firestone[1](chaz.firestone@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

We can quickly and effortlessly evaluate whether a tower of blocks will collapse or a stack of dishes will come crashing down. What is the nature of this ability? Although such "intuitive physics" are traditionally associated with higher-level reasoning, here we explore the possibility that such sophisticated physical intuitions are underwritten by more basic processes -- and specifically whether visual attention and memory are automatically drawn toward physically relevant features. In a modified change-detection task, an image of a physically stable block-tower was briefly displayed, after which it disappeared and was replaced either in the same configuration or with one block slightly displaced. On some trials, this change upset the tower's balance, rendering it unstable; on other trials, the change was identical in magnitude but did not alter the tower's stability. Detection was reliably better for changes to blocks that altered overall stability, compared to either (1) equivalent changes to the same blocks that did not influence stability, or (2) equivalent changes to different blocks. Critically, this pattern was robust even though stability was entirely incidental to the task. Follow-up studies demonstrated that improved change detection based on physical stability was reliable even when attending to physical stability could confer no strategic advantage, and was robust even for observers who never consciously noticed any variation in the towers' (in)stability. Further work isolated perceived stability, per se: when the towers' ground-truth stability (according to physics) was contrasted with subjectively perceived stability (as rated by independent subjects), change-detection was better predicted by how stable the towers *looked* than by how stable they actually were. Collectively, this work shows how basic processes of attention and memory are sensitive to a scene's underlying physics, and how selective attention is automatically drawn to those objects and features that are especially physically relevant.

36.4061 Changes in object salience influences overt attentional prioritization in natural scenes. Nicola Anderson[1](nccanderson@gmail.com), Mieke Donk[1]; [1]Cognitive Psychology, Vrije Universiteit Amsterdam

In the present work, we investigated the extent to which the prioritization of an object change was modulated by object salience in natural scene viewing. Scenes and objects were selected from the LabelMe database [Russell, B. C., Torralba, A., Murphy, K. P., & Freeman, W. T. (2008). LabelMe: a database and web-based tool for image annotation. International journal of computer vision, 77(1-3), 157-173.] and the salience of a selected object was manipulated by either increasing or decreasing the luminance contrast. In a task similar to that used in previous work [e.g., Brockmole, J. R., & Henderson, J. M. (2005). Prioritization of new objects in real-world scenes: evidence from eye movements. Journal of Experimental Psychology: Human Perception and Performance, 31(5), 857.], we asked observers to look around a scene in preparation for a later memory test. After a period of time, the salience of an object in the scene was changed, either during a fixation (transient signal) or during a saccade (non-transient signal). When object salience increased during a fixation, it was fixated sooner, and more often than when object salience decreased. Surprisingly, this was also the case when object salience increased during a saccade, albeit to a lesser extent. These results suggest that the prioritization of object changes can be influenced by the underlying salience of the changed object within the scene. We discuss these findings within the context of oculomotor selection based on the integration of feature-based and object-based representations of natural scenes.

36.4062 Task relevance modulates the representation of feature dimensions in the target template Reshanne Reeder[1](reshanne.reeder@ovgu.de), Michael Hanke[2,3], Stefan Pollmann[1,3]; [1]Department of Experimental Psychology, Institute for Psychology II, Otto-von-Guericke University, Magdeburg, Germany, [2]Psychoinformatics Department, Institute for Psychology II, Otto-von-Guericke University, Magdeburg, Germany, [3]Center for Behavioral Brain Sciences, Magdeburg, Germany

Previous studies have found a network from prefrontal to posterior parietal and ventral visual regions involved in feature-based attention control and task-relevant content representation. There is much debate about the different functions of these regions and where stimulus information is represented in preparation for visual search. Here we investigated the rep-

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resentational similarity between task-relevant and task-irrelevant feature dimensions during cue encoding and target template maintenance prior to search. Subjects were cued to search for a spatial frequency, orientation, or both features of a Gabor grating and we measured BOLD signal during the cue and delay periods before the onset of a search display. Univariate analyses revealed the cue and delay periods were functionally separable, in that BOLD signal amplitude was higher in posterior brain regions during the cue period, and in prefrontal cortex during the delay period. Using representational similarity analysis, we found that regions extending from lateral occipital complex to intraparietal sulcus and frontal eye fields showed correlated activation patterns within the task-relevant feature dimension and homogeneously different activation patterns in the task-irrelevant feature dimension. Furthermore, we observed that these patterns were stronger in the delay period than in the cue period, and were particularly strong along the left anterior intra-parietal sulcus (IPS). Left anterior IPS additionally showed significant differences in the representation of single features versus conjunctions in the delay period. Together these results provide evidence for task-specific representations activated in various cortical regions from cue processing to the active search period. Left anterior IPS may play a special role in distinguishing task-relevant and task-irrelevant feature dimension information during target template maintenance prior to visual search.

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36.4063 **Real objects elicit stronger affordance compatibility effects than images** Michael Gomez[1](michaelgomez@unr.edu), Jacqueline Snow[1]; [1]The University of Nevada, Reno

The term action affordance refers to the potential for manual interaction conveyed by the physical properties of an object; for example, the handle of a cup affords grasping. Using planar images of graspable objects as stimuli, studies have shown that responses are facilitated when the grasp response evoked by the image is compatible with a current action, and slowed when incompatible – a pattern classically referred to as 'affordance compatibility effects'. Here, we examined whether real-world objects that afford genuine motor interaction elicit stronger affordance compatibility effects than two-dimensional images, which are not inherently graspable. Participants searched a horizontal character array for one of two target letters, while ignoring an irrelevant distractor (cup) that appeared above or below the array. The handle of the cup was oriented so that it was either compatible, or incompatible, with the manual response in the search task. Critically, the distractor was either a real cup, or a two-dimensional high-resolution colored photograph of the cup. The image distractors were closely matched to their real-world counterparts for size, viewpoint, and illumination. We found that real cups elicited stronger response compatibility effects than the matched image distractors. Compared with image displays, therefore, real objects serve as more effective triggers for motor actions, possibly because of the potential they offer for genuine physical interaction.

36.4064 **Task-Defined Requirements of Attention and Global-Local Processing** Monica Rosen[1](rosen.monica@huskers.unl.edu), Mark Mills[1], Michael Dodd[1]; [1]Department of Psychology, College of Arts & Sciences, University of Nebraska-Lincoln

Global precedence refers to the notion that visual information at the global versus local-level is prioritized. This stems from studies showing that the global is identified faster and is more difficult to ignore than the local. Little is known regarding the prevalence of these effects beyond simple classification tasks. The present study explored the relationship between effects of attention (via manipulation of task relevancy) and global/local processing in the context of a higher-level problem solving task. Numerical Navon stimuli were presented as a math equation (e.g., "2 + 3", in which the global 2 and 3 consisted of smaller, homogeneous local numbers) for a variable duration. In one experiment, participants judged whether the number defining the local-level was the true/false answer to the global equation (local is task-relevant). In a second experiment, participants judged whether a single-level number presented after the compound equation was the true/false answer to the global equation (local is task-irrelevant). Response times (RTs) and error rates were considerably higher when the local-level was task-relevant versus task-irrelevant, indicating that task-driven processing of local information is effortful. When the local-level was task-relevant to solving the global equation, RTs increased and errors decreased with exposure to the compound equation, suggesting that participants tried to make greater use of local information the longer it was presented (reflected in longer RTs), which they were successful at (reflected in reduced error). When the local-level was task-irrelevant, RTs and errors decreased with exposure duration. Importantly, this performance benefit leveled off at longer exposures for RT but not errors, suggesting that local information delayed responses as it became more available with exposure. As the local-level was task-irrelevant, this suggests that processing of local information is obligatory with increasing exposure. Together, these findings indicate that processing of local information differs for task-relevant and task-irrelevant information.

36.4065 **Attentional priority signals in human frontoparietal cortex correlate with performance in a feature-based attention task** Michael Jigo[1](jigomich@msu.edu), Taosheng Liu[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

It is generally accepted that top-down visual attention selects goal-relevant stimuli to facilitate task performance. Hence, fluctuations in endogenous attentional control should influence performance in tasks relying on visual selection. Previous research has implicated a dorsal frontoparietal network in the maintenance of attentional priority for visual features. However, the relationship between the quality of these neural representations and task performance is not well understood. Using two speed detection tasks in an fMRI experiment, we tested whether the quality of an attentional priority signal, i.e., the neural representation of an attended direction of motion, correlated with task performance. In the attention task, subjects were cued to attend to one of two overlapping dot fields, one that rotated in a clockwise direction and another that rotated in a counter-clockwise direction. Subjects were instructed to report the presence or absence of a brief speedup in the cued direction. In the baseline task, subjects similarly reported the presence or absence of a speedup, but they only viewed a single dot field that rotated in either direction. The patterns of neural activity for correct and incorrect trials in each motion direction in the attention task were obtained as an index of the attentional priority signal. To get a measure of their respective quality, these priority signals were compared to the neural patterns obtained from the baseline task, which served as the benchmark. We found that attentional priority signals in parietal and prefrontal regions were more similar to the benchmark for correct than incorrect trials. This effect was less marked in early visual areas. These results revealed neural correlates of task performance for feature-based attention and suggest that parietal and prefrontal regions maintain attentional priority that facilitates the successful selection of relevant visual features.

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36.4066 **How is visual search guided by shape? Using features from deep learning to understand preattentive "shape space"** Krista Ehinger[1,2](k.a.ehinger@gmail.com), Jeremy Wolfe[1,2]; [1]Harvard Medical School, [2]Brigham & Women's Hospital

Visual search can be guided by target shape, but our understanding of how shape guides search has been limited a set of specific shape features such as curvature, closure, line termination, aspect ratio, or intersection type (see Wolfe & Horowitz, 2004, for a review). These features, while important, do not capture the full range of preattentive shape processing. Understanding how shape guides search more generally requires a model of preattentive "shape space" that correctly represents the similarity between a target shape and different types of distractors. Here, we investigate whether the features learned by "deep learning" convolutional neural networks (CNNs) can be used as a proxy for this shape space. Previous work has shown that the visual representations learned by these networks generalize surprisingly well to a range of visual tasks (Razavian, Azizpour, Sullivan, & Carlsson, 2014). Eight participants performed a visual search task where they searched for a randomly-rotated shape target (a butterfly or rabbit silhouette) among different types of randomly-rotated distractor shapes generated from a family of radial frequency patterns. To characterize the distractor shapes, we ran them through a CNN (Krizhevsky, Sutskever, & Hinton, 2012) and used the feature vector produced by the second-to-last layer of the network as candidate shape features. Easy and hard distractors for each target were well-separated in this shape space, and hard distractors tended to be closer to the target in the neural network's representation of shape. Different participants tended to converge to a similar part of the feature space for hard distractors, but there was less agreement on which distractors were easiest. Our results suggest that the visual representation learned by a "deep learning" CNN is a reasonable approximation of the perceptual space in which humans process shape.

36.4067 **Role of simple primitive shapes in complex distractors: Do shared features affect search times?** Ruggero Micheletto[1,2,3](ruggero@yokohama-cu.ac.jp), Krista Ehinger[1,2], Jeremy Wolfe[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School, [3]Yokohama City University, Japan

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A stochastic algorithm has been developed to generate distractor shapes for visual searches. These distractors evolve according to genetic rules from a random starting point. Nevertheless, using subject response times without any information about the target, it is possible to evolve distractors that make the target easy or hard to find in visual search. In one version, 12 subjects, searched for the silhouette of a rabbit. In each generation, each trial used one of 12 distractors. After 8 generations, distractors that make search hard were not identical to each other, nor did they look like rabbits. What makes a "hard" search? We hypothesize that there are primitive preattentive component shapes (Wolfe, 1996) that the visual system looks for during visual search for more complex items (e.g. rabbit). We chose six candidate preattentive rabbit components and use an adaptive generalized Hough transform to determine if these components became more evident of several 'generations' of evolution. The generalized Hough transform algorithm gives a measure of the extent to which a candidate primitive profile fits the distractor outline shape. It was found that the most difficult distractors do in fact contain more primitive features of the target; for example, the elongated ellipse of the rabbit's "ears". Evolution did not produce more of control primitives like triangles or squares. Results suggest that during search of complex shapes, the human visual system is not guided to the whole target but rather to a set of component shapes. These primitives may represent a preattentive language for shape processing.

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36.4068 **Statistical processing of perceptual groups under working memory load** Michael Epstein[1](mepstein@gradcenter.cuny.edu), Tatiana Emmanouil[2]; [1]The Graduate Center, CUNY, [2]Baruch College and The Graduate Center, CUNY

The visual system is capable of summarizing the average properties of sets of objects that exceed the limits of focused attention. While statistical processing is thought to involve distributing attention over the set as a whole, the possibility remains that it relies on the sampling of a few objects that remain within the limits of focused attention. In the present study we tested this question using a dual task paradigm. Participants performed a statistical processing task while maintaining items in working memory (colors in Experiment 1, spatial locations in Experiment 2). We hypothesized that even though working memory load would interfere with the encoding of individual items, it would not interfere with statistical processing accuracy. The difficulty of both the statistical processing and working memory tasks was varied: participants compared the average size of two sets of circles which differed by 5%, 10%, 15% or 20% in mean size, while maintaining two, four or zero items in working memory. In both experiments, participants performed less accurately in the statistical processing task as the difference in mean between sets decreased. Also, they showed expected memory accuracy decrements with increased memory load. However, as predicted, participants' performance in the statistical processing task was not influenced by working memory load. The results suggest that statistical properties are extracted from the set as a whole rather than from individually processed objects.

36.4069 **Measuring attentional deployment and sampling of multiple dynamic features within the same object** Chloe Callahan-Flintoft[1](ccallahanflintoft@gmail.com), Brad Wyble[1]; [1]Pennsylvania State University

The current research aims to investigate how attention samples information from dynamic stimuli. We measured participants' precision in reporting from continuously varying features (color and orientation) at a specific moment in time using a visual cue (a white circle around the target for 54ms). Participants first completed a perceptual matching and then a working memory matching block. These allowed participants to become comfortable with the continuous reporting scale and provided a baseline measurement of working memory precision. The next three test blocks were counterbalanced across participants where six shapes, located in a circle around fixation, rotated or changed in color through a cyclical vector at a rate of 4 degrees per 27ms. During each trial a cue was presented around one of the shapes and participants attempted to reconstruct the value of one or two features at the moment of the cue using continuous report with a mouse and visual feedback. In the orientation-only and color-only blocks one feature was held constant whilst the other was dynamic and subjects ignored the static feature. In the both-feature condition, both color and orientation were dynamic and participants reported both. Using a mixture model (Zhang & Luck, 2008) the mean shift and variance of the report errors were analyzed. It was found that in the single and double feature report, participants, on average were reporting the orientation and color value of the cued shape 189ms and 256ms, respectively, after the cue. Surprisingly there was little additional variance or delay in report errors when participants had to report two features instead of one. Furthermore, our results suggest independent access to the two features, given assumptions about the time to access features. These assumptions are characterized in three statistical models that compare simultaneous, sequential and independent access to two features of a single object.

36.4070 **Object-Based Attention Shift Direction Efficiency: Behavior and a Model** Adam Barnas[1](ajbarnas@uwm.edu), Adam Greenberg[1]; [1]Department of Psychology, University of Wisconsin-Milwaukee

Object-based attention (OBA) leads to preferential processing within the boundaries of a selected object. Pilz and colleagues (2012) demonstrated larger OBA effects for horizontal rectangles than vertical rectangles; these effects were eliminated when controlling for attention shifts across the visual field meridians (Greenberg et al., 2014). We recently showed that reallocation of OBA is faster horizontally than vertically (Barnas & Geenberg, 2015) when objects cross the meridians. The RT difference between horizontal and vertical shifts (Shift Direction Difference; SDD) was larger for uncued objects (~120ms) than cued objects (~80ms). Here, we aimed to further elucidate the modulatory role of the visual field meridians on OBA and to model the underlying components contributing to the SDD. In three experiments, we utilized an 'L'-shaped object comprised of a horizontal rectangle hinged to a vertical rectangle, sequestered into one screen quadrant. Following a partially valid peripheral cue, participants detected the presence of a target at a cued location (valid condition) or at one of two uncued locations (invalid conditions) equidistant from the cue in either the horizontal or vertical object component. SDD magnitude was significant when the cued object was near fixation (62ms), but not when the cued object was far from fixation (20ms). Based on these findings, in another experiment we accurately predicted SDD magnitudes for uncued objects near and far from fixation as 102 and 41 ms, respectively. Our behavioral results led to a model of SDD magnitude that incorporates effects of meridian crossings (horizontal vs vertical; ~40ms), object selection (cued vs uncued; ~40ms), and object vertex location (near vs far from fixation; ~60ms). Taken together, our findings necessitate updating current OBA theories to include effects of these three parameters, which seem to account for the often-reported difference in OBA shift direction efficiency between horizontally and vertically oriented objects.

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36.4071 **Reality vs. Simplicity: The Effects of Real-World Objects on Attentional Selection** Paul Scotti[1](shom@gwu.edu), George Malcolm[2], Mary Peterson[3], Sarah Shomstein[1]; [1]George Washington University, [2]University of East Anglia, [3]University of Arizona

Most object-based attention research over the past two decades has been conducted with simple, geometric objects (e.g., rectangles, semicircles, trapezoids, crossed lines, letters). This research has shown that, under specific circumstances, objects guide attentional selection in a predictable manner (Chen & Cave, 2006, 2008; Goldsmith & Yeari, 2003; Martinez et al., 2006; Richard, Lee, & Vecera, 2008; Shomstein & Behrmann, 2006, 2008; Shomstein & Yantis, 2002, 2004). Object-based guidance of attentional selection with simple objects is then assumed to transfer from the lab setting to complex objects in the real world. Here, we test this assumption by conducting a series of experiments that investigate whether real-world objects guide attention similarly to simple objects, and whether a set of circumstances that are known to yield differences in object-based guidance in simple objects (probability imbalances, reward biases) behaves similarly with real-world objects. It is not readily expected that object-based attention will be observed with real-world objects as those objects have more complex low-level (i.e., complexity of edges, frequency composition) and high-level (semantic information, learned associations) properties. We used a set of simple rectangles, 50 real-world objects with horizontal primary axis, and 50 real-world objects with a vertical primary axis (manipulated between subjects). We observed a robust object-based effect for real-world objects ($p < .002$), that was in fact greater than that observed for rectangles ($p < .05$). Additionally, we probed the robustness of this effect with various biases against the same object location (e.g., reward and probability). Our findings extend the literature on object-based attention to include real-world objects, and suggest that objects guide attentional selection even in complex environments that are full of low- and high-level variability.

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Visual Memory: Neural mechanisms

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4072 Two ways to remember: Properties of visual representations in Active and Passive Working Memory

Gi-Yeul Bae[1](freebird71@gmail.com), Steven Luck[1]; [1]University of California, Davis

Recent research suggests the existence of two neurophysiologically distinct working memory (WM) subsystems. One stores information actively by means of sustained activation maintained by recurrent feedback loops (WM-active), and the other stores information passively via rapidly decaying changes in synaptic efficacy (WM-passive). The present study tests the hypothesis that WM-active represents precise metric properties of visual stimuli and is needed to perform any non-automatic cognitive computations, whereas WM-passive represents information categorically and can be maintained during ongoing cognitive operations. To test these hypotheses, we used a dual-task paradigm in which participants performed a non-automatic letter discrimination during the retention interval of an orientation delayed estimation task (Attend-Letter condition). Participants ignored the intervening letter stimulus in a control condition (Ignore-Letter condition). We assessed the presence of WM-active by recording the EEG during the maintenance interval of the WM task and decoding the sample orientation (because EEG decoding is possible only with active representations). We predicted that the orientation would be displaced from WM-active by the intervening letter stimulus when this letter was being discriminated, eliminating the orientation information from the EEG, but the orientation would still be maintained in WM-passive. As predicted, we could decode the sample orientation during the retention interval in the Ignore-Letter condition, but the presentation of the letter eliminated this orientation information in the Attend-Letter condition. Analyses of behavioral responses showed that the orientation memory was less precise and more categorically biased in the Attend-Letter condition, in which the orientation was presumably stored in WM-passive but was no longer present in WM-active. Together, the present results indicate that (1) WM-active is needed for even simple non-automated tasks such as letter discrimination, and (2) WM-passive maintains visual information in a less precise and more categorical manner than WM-active.

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36.4073 Visual and parietal spatial working memory representations are robust to brief irrelevant distracters

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Visual working memory (WM) enables the maintenance and manipulation of information no longer accessible in the visual world. Previous research has identified WM representations in activation patterns in visual, parietal, and frontal cortex (Serences et al, 2009; Harrison & Tong, 2009; Ester et al, 2013; Sprague, Ester & Serences, 2014; Ester, Sprague & Serences, 2015; Bettencourt & Xu, 2015). In natural vision, the period between the encoding of information into WM and the time when it is used to guide behavior (the delay period) is rarely "empty", as is the case in most of the above laboratory experiments. In naturalistic conditions, eye movements, movement of the individual, and events in the environment result in visual signals which may overwrite or impair the fidelity of WM representations, especially in early sensory cortices. Here, we evaluated the extent to which a brief, irrelevant distracter stimulus presented during a spatial WM delay period impaired behavioral performance and WM representation fidelity assayed using an image reconstruction technique (inverted encoding model; Sprague, Ester & Serences, 2014). On each trial, participants viewed two target dots and were immediately post-cued to remember the precise spatial position of one dot. On 50% of trials, a 500 ms flickering radial checkerboard distracter stimulus (40% contrast) appeared; on the other 50% of trials, no distracter appeared. While we observed strong transient univariate visual responses to the distracter stimulus, we saw no change in the fidelity of reconstructed neural WM representations under distraction, nor a change in behavioral performance on a continuous recall task. These results suggest that spatial WM representations may be particularly robust to interference from incoming visual information, perhaps related to their role in guiding movements.

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36.4074 Effects of distractors on visual working memory representations

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Visual working memory (VWM) allows for the maintenance of precise visual details of objects no longer in view, and is supported by activity in many brain regions, including lateral prefrontal cortex (D'Esposito et al., 1995, 1996) and primary sensory cortices (Harrison & Tong, 2009). While "sensory recruitment" models (D'Esposito, 2007; Postle, 2006) suggest that precise visual details are maintained in stimulus-selective primary visual regions, it remains unclear what happens to VWM representations in the face of subsequent visual input. In this experiment, we examine whether, and where, tuned VWM representations persist through an irrelevant distractor, and whether subsequent VWM orientation tuning is biased toward the orientation of the distractor. Functional magnetic resonance imaging (fMRI) data was collected while participants performed a delayed-estimation task for right-lateralized oriented gratings. On 2/3 of trials, a distractor grating appeared midway through the 20-s trial in the same spatial location as the initial memory cue, rotated between 40 and 50° clockwise or counterclockwise of the remembered orientation. We employed a forward encoding modeling approach (Brouwer & Heeger, 2011; Ester et al., 2013) to reconstruct orientation tuning functions reflecting the accuracy and precision of orientation representations during 1) stimulus perception, 2) memory maintenance, 3) distractor perception, and 4) memory maintenance following distraction. Reliable orientation tuning was observed during stimulus perception in the contralateral, but not ipsilateral, early visual areas (V1-V3). However, the representations spread to bilateral V1-V3 over the memory maintenance interval. During distractor presentation, tuning for the remembered orientation persisted in both hemispheres, although tuning was considerably weakened in the hemisphere contralateral to the distractor. Finally, the tuning curves in bilateral V1-V3 were biased toward the distractor orientation after the distractor offset, and there was a small but significant behavioral bias in the same direction.

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36.4075 Plasticity of prefrontal cortical responses during learning in a working memory task

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Training to improve working memory is associated with increased BOLD signal from the lateral prefrontal cortex and confers lasting cognitive benefits in humans. The neural substrate underlying these changes is poorly understood. In a previous series of experiments we identified increases in prefrontal activity after training monkeys in working memory tasks. However, these experiments provided only snapshots of changes at the start and end of training. To assess how brain changes are effected by different aspects of training, we recorded neuronal activity with a chronic 64-electrode array in the prefrontal cortex of 2 monkeys, as they learned to perform a visuo-spatial working memory task. We re-sampled the same cortical locations every day, which provided an unbiased cross-section of population activity. Training involved three stages. First, the monkey was presented with two stimuli in rapid succession and had to indicate if they appeared at the same or different location by selecting one of two saccade targets signifying match or non-match. Second, the monkey had to generalize the task to new stimuli, appearing at any location. Third, an increasing delay period was imposed, placing more demand on working memory. Visual stimuli were also presented passively in a fixation task. A total of 736 multi-unit activity (MUA) records were selective for the location of the stimuli (ANOVA, $p < 0.05$). MUAs obtained at each subsequent stage of training were characterized by increased firing rate during the stimulus presentation and the delay period. Interestingly, increased rate was also observed during the fixation task. The findings demonstrate that working memory training induces plastic formation of new visually responsive cell assemblies. Increases in the proportion of activated neurons and discharge rate may have been underestimated by single-electrode recordings. The results also demonstrate that activity changes induced by training transfer between stimuli and task conditions.

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36.4076 **Visual working memory enhances neural representations of matching visual input** Surya Gayet[1](s.gayet@uu.nl), Matthias Guggenmos[2], Thomas Christophel[3,4], John-Dylan Haynes[3,4,5], Chris Paffen[1], Stefan Van der Stigchel[1], Philipp Sterzer[2,3,5]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, Netherlands, [2]Visual Perception Laboratory, Department of Psychiatry and Psychotherapy, Charité Universitätsmedizin, Berlin, Germany, [3]Bernstein Center for Computational Neuroscience, Berlin, Germany, [4]Berlin Center for Advanced Neuroimaging, Charité Universitätsmedizin, Berlin, Germany, [5]Berlin School of Mind and Brain, Humboldt Universität, Berlin, Germany

Visual information that is actively maintained in working memory has been shown to affect concurrent perception. One possible explanation is that working memory and sensory representations embody a common neural substrate. Here, we hypothesized that visual information maintained in working memory should enhance concurrent processing of visual input that matches the content of working memory. To test this hypothesis, 15 participants performed a delayed match to sample task during fMRI scanning. Participants were sequentially presented with two central shape stimuli, drawn from three shape categories (rectangles, ellipses and triangles), and a postcue. The postcue indicated which of the two shapes should be memorized for subsequent recall. During the retention interval a different shape was presented that either matched the category of the cued (memorized) shape or the uncued shape, or was of the hitherto unused shape category. This task-irrelevant shape stimulus was presented peripherally for one second at an unpredictable delay and location. The results revealed that those brain areas that responded to the occurrence of the shape stimulus per se (including parietal and ventral occipital cortex) showed increased activation when its shape category matched the memorized shape category, despite identical visual stimulation in mismatching trials. Next, we assessed whether the quality of the neural representation was modulated by the content of visual working memory as well. Multivariate pattern analysis allowed for decoding the shape category of the task-irrelevant shape stimulus when it matched, but not when it mismatched, the memorized shape category. Together, our results demonstrate enhanced visual processing of stimuli that match the content of working memory. This enhanced response might underlie a plethora of well-known behavioral phenomena, such as the finding that visual input that matches rather than mismatches the content of visual working memory attracts attention and eye movements, and gains preferential access to awareness.

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36.4077 **Transcranial Direct Current Stimulation Modulates Pattern Separation** Marcus Cappiello[1](mcapp001@ucr.edu), Weizhen Xie[1], Alexander David[2], Marom Bikson[2], Weiwei Zhang[1]; [1]Department of Psychology, University of California, RIverside, [2]Department of Biomedical Engineering, The City College of New York of CUNY

Representing similar stimuli and events in a distinct and non-overlapping fashion, known as pattern separation, is pivotal for normal memory function. Hippocampus and surrounding medial temporal lobe (MTL) structures, such as the perirhinal cortex, have been implicated in pattern separation. The present study tested effects of transcranial Direct Current Stimulations (tDCS) over temporal lobe on pattern separation to determine the causal role of temporal lobe structures in pattern separation, which was assessed with the Mnemonic Similarity Task (MST). In this task, participants studied a series of sequentially presented visual objects. In the subsequent recognition memory test, participants viewed a series of sequentially presented objects that could be old images from study, novel foils, or lures that were visually similar to the studied images. Participants reported whether these images were exactly the same as, similar to, or different from the studied images. Following 15-minute offline bilateral temporal lobe tDCS (both the left cathode and right anode (L-R+) and the left anode and right cathode (L+R-) configurations), participants were less likely to identify lures as ‘‘similar’’ compared to the sham condition, indicating an impairment in pattern separation resulting from temporal lobe tDCS. In contrast, no significant difference in overall accuracy was found for participants' discrimination of old and new images. Together, these results show that temporal lobe tDCS specifically modulates pattern separation function without changing participants' baseline recognition memory performance, suggesting a causal role of temporal lobe structures in pattern separation.

36.4078 **Event-related contralateral delay activity: A measure of working memory maintenance or the allocation of spatial attention?** Nick Berggren[1](nbergg01@mail.bbk.ac.uk), Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, UK

Retaining visual information in working memory (WM) results in a sustained event-related potential over occipital regions, contralateral to the side of space where memorised information is located, known as contralateral delay activity (CDA). Given its relationship to memory load and individual differences in memory performance, the CDA component is often interpreted as a neural marker of active WM maintenance/storage. However, the CDA could also reflect the allocation of spatial attention to task-relevant locations within WM. To assess this, we conducted a sequential load task where participants memorised four items that were presented in two successive displays (M1 and M2; e.g., two item at M1, then a further two items at M2). In Experiment 1, CDA components were elicited contralateral to to-be-memorised items at M1. Critically, CDA components switched polarity after M2 was presented on trials where relevant stimuli appeared in opposite hemifields. CDA components to M1 stimuli were also significantly reduced after M2 stimuli were presented non-laterally (Experiment 2). This suggests that the CDA is primarily driven by the current focus of attention rather than WM maintenance per se. However, there were also small increases of CDA amplitude after M2 presentation when M1 and M2 stimuli appeared at the same location, and also when M1 and M2 stimuli appeared at different locations in the same hemifield (Experiment 3). Overall, our results suggest that the CDA component is predominantly a reflection of the focus of spatial attention during WM maintenance. However, the CDA amplitude increase observed when additional stimuli are maintained within the same hemifield may indeed signify WM storage.

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36.4079 **What to do with Low-Priority Items: an ERP study of Resources Allocation in Visual Working Memory** Holly Lockhart[1](hl10ze@brocku.ca), Stephen Emrich[1]; [1]Brock University, Psychology Department

Visual working memory (VWM) is a limited resource, which may be distributed discretely or continuously, as predicted by opposing theoretical models. When presented with distracting information, it is most efficient to ignore or minimally process it. However, in many situations some items are more relevant than others and the target/distractor distinction is less clear. In a discrete resource allocation model, distractor items should be ignored completely to process target items in the limited slots of memory. In contrast, in the continuous model, distractors may be processed minimally with preference given to target items. One event-related potential (ERP) associated with VWM is sustained posterior contralateral negativity (SPCN), which is typically shown to scale with increasing load. In the present study, we used the SPCN to determine the extent to which low-priority items are processed. Participants were presented with four lateralized coloured objects while recording ERPs in three cue conditions: one-cue with 100% validity (no priority to non-target items), one-cue with 50% validity (low-priority to non-target items), and four-cues with 100% validity (all items given priority). In the 50% valid condition any of the uncued items could be probed; thus, these items should be allocated a portion of VWM resources in order to report the colour correctly. Results demonstrate that in the low-priority condition the SPCN amplitude was between the one-cue and four-cue conditions; thus, these items are not processed as targets (as in the four-cue condition) or ignored (as in the one-cue condition), but are meaningfully processed according to their priority. Further, frontal markers indicate that this condition required more executive control to preferentially maintain target items while meaningfully holding the low-priority items in memory. These results suggest that ERP markers of VWM maintenance reflect minimal but meaningful processing of low-priority items, as predicted by a continuous resource model.

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36.4080 **Local and interregional alpha oscillatory dynamics are sensitive to different levels of working memory-guided visual search** Joram van Driel[1](joramvandriel@gmail.com), Eren Gunseli[1], Martijn Meeter[1], Christian Olivers[1]; [1]Vrije Universiteit Amsterdam, department of Cognitive Psychology

Attention during visual search is thought to be guided by an active visual working memory (VWM) representation of the search target. However, it is unclear if and how neural mechanisms that support VWM dissociate between different levels of anticipated search difficulty. We tested the hypothesis that posterior alpha band (8–14 Hz) oscillatory dynamics

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during VWM encoding and maintenance of the search target, are sensitive to the anticipated level of competing information present during search. To this end, we analyzed an existing EEG dataset from 20 human subjects while they performed three different VWM tasks. Each task started with a lateralized cue as to which target to look for in a subsequent search display that was presented after a one second delay. In one task subjects had to recognize the target without distractors. In the other two tasks, recognition after the delay was compromised by competing distractors in a pop-out (distinct), or serial (non-distinct) search display. Behavioral performance decreased with increasing search difficulty. During the delay period, parieto-occipital sites contralateral to the WM cue exhibited robust alpha power suppression, as well as reduced alpha phase synchronization with mid-parietal sites. This oscillatory signature of VWM maintenance, importantly, was strongest prior to non-distinct search and weakest prior to simple recognition. Functional connectivity analyses further showed that, before WM cue-onset, alpha phase synchrony between prefrontal sites and mid-parietal sites was strongest in the non-distinct search task, possibly reflecting anticipatory control of VWM encoding. Directional connectivity analyses confirmed this effect to be in an anterior-to-posterior direction. Together, these results provide evidence for frontally mediated top-down control of VWM in preparation of visual search.

36.4081 **Tracking the dynamics of visual working memory representations using steady-state-visual-evoked potentials**

Anouk van Loon[1](anouk.vanloon@gmail.com), Constantina Archeo[1], Chris Olivers[1]; [1]Department of Cognitive Psychology, Vrije Universiteit Amsterdam

Recent studies have revealed that items held in visual working memory (VWM) change their status depending on task-relevance. Here, we used steady-state visual evoked potentials (SSVEPs) to track the dynamics of these state changes during a combined visual search and working memory paradigm. Participants memorized two coloured items, followed by a cue that indicated which item needed to be searched for first (creating an attentional template for current task-relevant information) and which second (creating an accessory memory for later use). Peripheral checkerboards that matched the colors of the attentional template and accessory item as well as an irrelevant control color flickered at unique frequencies during a retention interval and the two searches, enabling the simultaneous tracking of both types of memory. We observed differences in occipital SSVEP amplitudes depending on the status (e.g. task-relevance) of the memory items. More specifically, the amplitude of the color matching the current attentional template was higher compared to the accessory and irrelevant colors during both the retention interval and the second search, indicating enhanced activation of the template. However, surprisingly, during the first search we did not find this enhancement of the template. A difference in cognitive demand between the two searches could underlie this difference. Taken together, we demonstrate that items held in VWM can adopt a different status depending on task-relevance and that SSVEPs provide a useful tool in studying these dynamics.

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36.4082 **Alpha-band and raw EEG reflect distinct maintenance mechanisms during working memory**

Johannes Fahrenfort[1](fahrenfort.work@gmail.com), Jonathan van Leeuwen[1], Joshua Foster[2], Edward Awh[2], Chris Olivers[1]; [1]Department of Cognitive Psychology, Vrije Universiteit Amsterdam, [2]Department of Psychology and Institute for Mind and Biology, University of Chicago

Recent work has shown the ability to decode working memory contents from EEG measurements. Here we investigate to what extent the type of representation underlying this decoding ability changes for different types of tasks. We employed two working memory tasks with identical items, but different task requirements. The memoranda always consisted of oriented bars. At test time however, participants either had to reproduce the correct orientation by clicking on a location in space (a more spatially oriented task), or they had to identify the correct orientation among competing similarly oriented bars, as in visual search (a task that we hypothesized relies more on maintaining the actual orientation). Decoding on induced time-frequency decomposed measures of the EEG revealed higher decoding accuracy within the alpha band for the task that favors spatial maintenance compared to the task that was assumed to rely more on the actual orientation (consistent with the assumed role of alpha in spatial attention and working memory). Interestingly, using decoding on the raw EEG signal, we were able to track the remembered orientation at similar levels of accuracy across both types of task. The interaction between task type and EEG measure suggests that induced alpha and raw EEG reflect partially distinct types of representation maintained for these tasks, the first related to spatial attention, while the second may represent additional orientation-related information.

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36.4083 **Alpha-Band Power and the Maintenance of Information in Visual Short-Term Memory.**

Andrew Heinz[1](andrew.j.heinz@gmail.com), Jeffery Johnson[1]; [1]Center for Visual and Cognitive Neuroscience, Psychology, North Dakota State University

Studies exploring the role of neural oscillations in cognition have revealed sustained increases in alpha-band power (ABP) during the delay period of verbal and visual short-term memory (STM) tasks. There have been various proposals regarding the functional significance of such increases, including the inhibition of task-irrelevant cortical areas, and the active retention of information in STM. The present study attempts to delineate between these two alternatives. In pursuit of this aim we recorded EEG while participants performed a delayed recall STM task. In this task, participants were required to maintain the orientation of a single Gabor patch across a brief delay. On each trial, a second, task-irrelevant Gabor, varying in terms of similarity to the remembered target, was presented mid-way through the delay. To examine the functional relevance of patterns of ABP, we used a forward encoding model of orientation tuning to calculate orientation-specific channel tuning functions (CTFs) across each delay (both before and after the distractor). We reasoned that, if the pattern of delay-period ABP observed at occipital-parietal electrode sites reflects the mnemonic information used to support performance in the recall task, item identity should be decodable from this distributed pattern both prior to and following presentation of the distractor. Contrary to this possibility, we found that although the CTF derived from the delay period prior to the distractor was selective for target identity, the CTF derived from the second, post-distractor, delay was not. Additional analyses revealed that the amplitude of the distractor-evoked response (d-ER) differed as a function of CTF amplitude and dispersion: higher amplitude d-ERs were associated with higher dispersion and lower amplitude CTFs. These findings suggest that delay-period ABP supports STM by selectively inhibiting task-irrelevant features during maintenance. Ongoing analyses are focused on teasing apart interactions between target-distractor similarity, estimated CTFs and behavior.

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36.4084 **Contralateral delay activity predicts the affective consequences of ignoring items in visual working memory**

David De Vito[1](ddevito@uoguelph.ca), Mark Fenske[1], Naseem Al-Aidroos[1]; [1]Department of Psychology, University of Guelph

One consequence of ignoring visual objects in our environment is that we subsequently like those objects less; a stimulus-devaluation effect linked to attentional inhibition. While such 'inhibitory devaluation' has been well studied using perceptual tasks, little is known about the affective consequences of inhibition at later stages of representation. In the present experiment we combined behavioral and electrophysiological measures to examine inhibitory devaluation of items maintained in visual working memory (VWM). We specifically used the contralateral delay activity (CDA) event-related potential to investigate the immediate consequences of ignoring objects stored in VWM and whether changes in CDA amplitude are associated with the subsequent devaluation of ignored objects. Each trial of the experiment consisted of two tasks: a VWM test and a stimulus affective rating. Participants memorized three colored squares located on one side of a lateralized memory array. During the retention interval, a retro-cue was presented specifying with 100% validity that their memory of the cued item would be tested, and that the two un-cued items could be ignored. We found significant devaluation of un-cued stimuli relative to cued stimuli. Moreover, individual differences in the magnitude of devaluation were correlated with post retro-cue CDA amplitude ($r=-.60$), and with an earlier negative-going potential that resembled the latency and scalp distribution of an attention-related N2pc component time-locked to the retro-cue ($r=-.59$). However, differences in stimulus devaluation did not correlate with components prior to the retro-cue. Together, these electrophysiological results converge with our recent demonstration that the affective consequences of inhibition are the same for items represented solely in visual working memory as they are for sensory stimuli appearing in the external environment. More broadly, these results add to the growing literature comparing internal and external attentional mechanisms by demonstrating that attentional inhibition leads to the devaluation of distracting stimuli within both domains.

Acknowledgement: NSERC

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Face Perception: Mechanisms and models 1

Sunday, May 15, 2:45 - 6:45 pm
Poster Session, Pavilion

36.4085 Coding facial identity: Evidence for a channel tuned to the average (norm) face Linda Jeffery[1](linda.jeffery@uwa.edu.au), Nichola Burton[1], Stephen Pond[1], Colin Clifford[2], Gillian Rhodes[1]; [1]ARC Centre of Excellence in Cognition and its Disorders, The University of Western Australia, [2]UNSW Australia

Face identity can be represented in a multi-dimensional space with the average at the center. Considerable evidence suggests that this average acts as a perceptual norm, yet it is not clear how this norm is neurally coded. It has been proposed that each dimension of face space is coded by only two, oppositely-tuned, channels, each responding most strongly to one end of the dimension. On this view the average is coded implicitly by equal activation of both pools. An alternative account posits a third channel, tuned explicitly to the average (i.e., center of a dimension). We used two face identity aftereffect paradigms to distinguish between these two possibilities and to rule out a third possibility, narrow-band multichannel coding, in which there is no norm. In Experiment 1 we show that as adaptors become more extreme along a dimension aftereffects initially increase sharply and then plateau. Crucially there is no decrease, even for very extreme adaptors, ruling out a narrow-band multichannel account but consistent with both two-channel and three-channel accounts. In Experiment 2 we distinguish between these latter two models. To do so we measured how the range of faces identified as the average was affected by two adapting conditions - adapting to alternating images from opposite ends of an identity trajectory (e.g., Dan, AntiDan) and adapting to the average (i.e. the center of the trajectory). A two-channel model predicts similar effects for both adapting conditions, whereas a three-channel model predicts opposite effects for the two conditions. We found opposite effects: Alternating adaptation widened the range of faces identified as the average whereas adaptation to the average narrowed the range. These data provide evidence for explicit coding of the norm.

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36.4086 The Relative Role of Viewpoint and Identity in the Neural Representation of Faces in Fusiform Gyrus Katja Weibert[1](kw783@york.ac.uk), Timothy Andrews[1]; [1]Department of Psychology, University of York, York YO10 5DD, UK

Models of face processing propose that the fusiform face area (FFA) plays an important role in processing invariant aspects of faces such as identity. Recent studies have shown that patterns of response in the FFA can successfully decode individual identities across different viewpoints. However, other studies have reported that patterns of response in the FFA can successfully decode different viewpoints across different identities. Thus, the relative role of identity and viewpoint on the pattern of neural activity in the FFA remain unclear. Here, we used fMRI and a correlation-based MVPA to explore how identity and viewpoint of faces is represented in the fusiform gyrus. A 3 x 3 design was used with faces from three different identities shown from three different viewpoints. The faces from each identity were familiar to participants across the different viewpoints. Images from each condition were presented in a blocked design. To test the contribution of identity and viewpoint to the neural responses, we used a representational similarity analysis in which model correlation matrices were generated that represented the extreme cases where the patterns of response are entirely predicted by the identity or by the viewpoint. These models were then used in a multiple regression analysis of the fMRI data. The results showed that viewpoint explained significantly more variance than identity in the fusiform gyrus. Next, we asked whether low level visual properties could explain these patterns of neural response. A strong positive correlation between the neural patterns and the underlying low-level image properties was evident in the fusiform gyrus. Our results suggest that the differential role of viewpoint and identity might reflect differences in the image properties conveyed by these facial cues.

Acknowledgement: KW was supported by a studentship from the University of York.

36.4087 Brain Regions Selective for Face Recognition and Memory Processing Can Predict Performance on the Taiwanese Face Memory Test (TFMT) Gary Shyi[1,2,3](cwshyi@gmail.com), Peter Cheng[1,2], Varden Hung[1,2], Emily Lin[1,2], Tina Huang[1,2]; [1]Department of Psychology, National Chung Cheng University, [2]Center for Research in Cognitive Sciences, National Chung Cheng University, [3]Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University

Face recognition and memory entail not only encoding the perceptual input of a face upon its presence but also retrieving a relatively permanent representation in spite of variation in illumination, pose, an/or expression. For more than two decades, a network of face-selective regions has been identified as the core system of face processing, including occipital face area (OFA), fusiform face area (FFA), and posterior region of superior temporal sulcus (pSTS). However, recent studies have proposed that ventral route of face processing and memory ends at the anterior temporal lobes (i.e., vATLs), which may play an important role bridging face perception and face memory. Here we examined whether neural activity in vATLs can effectively predict performance on a face memory test that requires recognition circumventing variations in pose and lighting. To that end, we first identified during the functional scan the core face network by asking participants to perform a one-back task, while viewing either static images or dynamic videos. Compared to static localizers, dynamic localizers were far more effective identifying regions-of-interest (ROIs) in the core face processing system. We then determined for each ROI (OFA, FFA, pSTS, and vATL), the cluster size associated with maximum face selectivity. Participants were called back with various delays to perform a variety of face processing tasks, including the Taiwanese Face Memory Test (TFMT), which was constructed largely following Cambridge Face Memory Task (CFMT) and used images drawn from a recently established Taiwanese face database. Like CFMT, TFMT was administered in three consecutive stages with increasing reliance on robust face representations. Correlation analyses revealed that participants with greater neural adaptation in the right vATLs demonstrated better recognition and memory performance on TFMT, suggesting that individual differences in constructing invariant and robust neural representation of faces can predict behavioural performance on face recognition and memory.

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36.4088 Predicting and categorizing online video success from a computational model of face personality judgments Samuel Anthony[1](santhony@wjh.harvard.edu), Ken Nakayama[1]; [1]Department of Psychology, Harvard University

There is an extensive literature on the ability of humans to predict a range of outcome measures (including electoral success, teacher ratings, and corporate profits) from impoverished "thin slices" comprising brief videos or still images of an individual face. Data-driven approaches to quick, unreflective personality judgments (Oosterhof & Todorov 2008, Vernon et al. 2014) have shown that relatively stable components emerge from principal component analysis of unconstrained descriptions of personality traits. In our previous work (Anthony et al., VSS 2015) we have shown that a simple V1-like feature set is sufficient to build a computer vision model capable of explaining a significant percentage of reliable human judgments of face personality traits. The traits we have investigated, which include trustworthiness, dominance, age and intelligence, are highly correlated with the initial principal components derived in the work of Oosterhof and Todorov and Vernon et al. In the present work, we investigate whether the computational models we have developed have the power to predict relevant outcome measures for online video content. We generated trait ratings for trustworthiness, dominance, perceived age and IQ for all detected faces in frames sampled at 3 fps from a corpus of tens of thousands of YouTube videos. For a majority of keywords investigated mean scores of at least one model correlated significantly with view counts. We categorized these videos by commonly-occurring keyword and investigated what combination of model outputs was best able to predict the number of views received by videos tagged with that keyword. These trait signatures were highly characteristic for specific keywords and reliable within a given keyword. Using these trait signatures, a clustering or taxonomy of youtube content types is possible, where keyword-tagged types are grouped by the perceived facial traits (of individuals featured in that content) that correlate with video popularity.

36.4089 **Verifying Face Selectivity in the Human Prefrontal Cortex: Data from ~500 Participants** Annie Chan[1,2](wchan2@uthsc.edu), Aaron Trefler[3], Abbas Babajani-Feremi[1,2]; [1]College of Medicine, University of Tennessee Health Science Center, [2]Le Bonheur Children's Hospital, Memphis, [3]Laboratory of Brain and Cognition, National Institute of Mental Health

Numerous neuroimaging studies have identified an extended network of face responsive regions in the human brain. For example, robust activations for face stimuli have been found along the fusiform gyrus, the superior temporal sulcus, and in the anterior temporal lobe. Recent functional MRI (fMRI) studies in humans and monkeys have also reported face patches in the lateral prefrontal cortex in the absence of working memory demands, confirming findings from early electrophysiological studies in monkeys. Further investigation has demonstrated that this face activation is confined to the right inferior frontal junction (IFJ), with stronger response elicited by pairs of eyes than faces with eyes covered (Chan & Downing 2011; Chan 2013). However, many of these studies have only recruited a handful of participants. Here, we aimed to further investigate the topographical location of this prefrontal face activation and its response properties with a big dataset. Using fMRI data of ~500 healthy adults from the Human Connectome Project, our preliminary results showed activation beyond the IFJ when contrasting faces with objects. Two additional areas also elicited strong activation for faces, one above the IFJ near to the frontal eye field, another anterior to the IFJ. These strong activations were observed across both hemispheres. Individual subject region-of-interest analysis showed that these prefrontal areas produced different patterns of selectivity, suggesting that there are pockets of strong responses to visual categories, which may reflect some sort of underlying organizational principle for visual processing. Resting-state functional connectivity analysis with IFJ as a seed region showed a much stronger correlation with the superior temporal sulcus and middle temporal gyrus, indicating that these lateral regions may extract similar visual properties during face processing. Overall, this study verifies the presence of visual category information in the human prefrontal cortex in a larger population.

36.4090 **Extracting Human Face Similarity Judgments: Pairs or Triplets?** Linjie Li[1](lil121@ucsd.edu), Amanda Song[2], Vicente Malave[2], Garrison Cottrell[3], Angela Yu[2]; [1]Electrical and Computer Engineering Department,University of California San Diego, [2]Cognitive Science Department,University of California San Diego, [3]Computer Science Engineering Department,University of California San Diego

Understanding how humans assess facial similarity is an important problem for both machine learning applications and cognitive science. Two classical techniques for extracting human similarity judgments are in broad use, pairwise rating and triplet ranking. While there are obvious algorithmic consequences based on these methods, there has been little explicit comparison of the informational utility of the two. Here, we present face similarity judgment data, in both pairwise and triplet forms, collected on Amazon Mechanical Turk. We demonstrate that triplet data are more informative of both individual judgments and heterogeneity among individuals. In the experiment, we present seven faces to each subject in both formats, for a total of 35 triplets and 21 pairs, repeated 4 times. We use the 10k US Adult Faces database provided by Aude Oliva's group at MIT. We convert the pairwise data into equivalent triplet data, and then use identical measures to compare the two. We first compute the cross-correlation over repeated responses for each triplet, and find that the self-consistency is higher for triplet data. Moreover, cross-correlation of responses across subjects for the same triplets suggests distinct subgroups of individuals, and this multi-cluster pattern is less evident in the equivalent pairwise data. We further propose a statistical model to quantify the information gain of both methods and our results suggest that triplets indeed provide more information than pairs. Overall, triplet ranking is more informative than pairwise rating for eliciting facial similarity judgments from humans. It has often been observed that humans give more self-consistent responses when reporting relative preferences than assigning numeric values to individual items, especially in complex judgments involving high-dimensional inputs. Apparently, forcing humans to assign numerical values to complex judgments can not only make them appear less consistent, but also can corrupt the information available in simpler relative ranking responses.

36.4092 **rTMS to the OFA shows increased correlation to right and left FFA** Francisco Parreira[1](franparr@yorku.ca), Sara Rafique[1], Lily Solomon-Harris[1], Jennifer Steeves[1]; [1]Centre for Vision Research, York University

Face processing is one of the most developed visual skills in humans, giving us the ability to quickly and accurately perceive the unique identity of an individual and guide our social interactions. Functional magnetic resonance imaging (fMRI) shows that brain areas such as the fusiform face area (FFA), the superior temporal sulcus (STS), and the occipital face area (OFA) form a network of key face processing regions. We sought to measure the level of functional synchrony within and across hemispheres in the face network. We measured the effect of repetitive transcranial magnetic stimulation (rTMS) to the right OFA on BOLD signal within the face network using a consecutive TMS-fMRI paradigm. Participants underwent 20 min of 1Hz rTMS followed by an fMR-adaptation paradigm. In separate sessions in counterbalanced order, rTMS was delivered in three different conditions: 1) rTMS to the right OFA, 2) sham rTMS, and 3) the control region, right lateral occipital area (LO). rTMS was immediately followed by a face-adaptation fMRI task to measure its effects on BOLD signal. Prior to the rTMS sessions participants underwent two functional localizers in order to extract individual face-processing regions-of-interest (ROIs). Individual Pearson's Correlation Coefficient (PCC) matrices were constructed across ROIs in the different TMS conditions. There was a general increase in the correlation between FFA and OFA BOLD signal in the right and left hemispheres after rTMS to the right OFA compared to sham and TMS to LO conditions. TMS to the OFA reduced BOLD signal, which correlated with a reduction in BOLD signal in the left OFA and bilateral FFA. These results are consistent with previous findings showing that TMS to the OFA has remote effects in the FFA both within and across hemispheres.

36.4093 **What is the division of labor between the two face pathways?** Michal Bernstein[1](michal100888@gmail.com), Yaara Erez[2], Galit Yovel[1,3]; [1]Sagol School of Neuroscience, Tel Aviv University, Israel, [2]Cognition and Brain Sciences Unit, MRC, Cambridge, UK, [3]School of Psychological Sciences, Tel Aviv University, Israel

The most dominant neural model of face processing posits that the face network is composed of two pathways that process different types of facial information (Haxby et al. 2000): A ventral pathway processes invariant aspects such as identity and gender and a dorsal pathway processes changeable aspects such as expression and gaze. This model is primarily based on studies that presented static images of faces. Recent studies that presented dynamic faces show that the dorsal stream is highly responsive to dynamic faces, whereas the ventral stream shows similar response to static and dynamic faces (Pitcher et al. 2011). These recent findings raise the question of what is the primary division of labor between the two pathways: is it to motion and form? to changeable and invariant facial aspects? or the interaction of both. To answer this question, we presented dynamic and static faces while subjects performed either an expression (positive/negative) or a gender (male/female) discrimination task. Univariate analysis revealed higher response to the dynamic than static faces in the dorsal pathway, whereas the ventral pathway responded similarly to the dynamic and static conditions. Both face streams showed no effect of task. Multivariate analysis further revealed that the dorsal but not the ventral regions carry information about motion, indicated by higher correlation within than between moving and static stimuli. Neither the ventral nor the dorsal streams carried information on whether subjects performed an expression or a gender task. Finally, the pattern of response in the motion area, MT, was correlated with the response of the dorsal face stream, further indicating its primary response to motion. These findings suggest that the primary division of labor between the two face streams is to motion and form rather than to changeable and invariant aspects, as current models posit.

36.4094 **Comparing the specialization for facial motion in macaques and humans** Molly Flessert[1](molly.flessert@nih.gov), Hui Zhang[1], Shruti Japee[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health

Dynamic faces convey a wealth of social information. Both macaques and humans depend on facial motion to facilitate the recognition of facial expression in their social interactions. However, the extent to which the specialization for facial motion is represented in the visual systems across the two species remains unclear. Here, we used fMRI to investigate this issue. Four male macaque monkeys were scanned at 4.7T. During scanning, they viewed blocks of dynamic neutral monkey faces, dynamic common objects, static neutral monkey faces, and static common objects. Sixteen human subjects participated in a similar experiment at 7T. Participants viewed blocks of identical stimulus categories, except they viewed human faces. For both monkeys and humans, the static face/object stimuli were extracted from the corresponding dynamic video stimuli. Motion energy in the dynamic face blocks was equated to that in the dynamic object blocks. General linear model analyses were performed on whole brain fMRI data to evaluate the fMRI responses evoked by the four stimulus categories. The contrast of the fMRI response to motion caused by faces (dynamic faces versus static faces) relative to the responses to motion caused by objects (dynamic objects versus static objects) defined the brain areas selective for facial motion. Our results showed that, in all monkeys, significant activations evoked by facial motion were found in the anterior superior temporal sulcus (STS), within the anterior fundus face patch bilaterally (p< 0.001). In humans, facial motion activated three separate foci in the right STS (p< 0.001): anterior STS, middle STS and posterior STS, with the anterior STS focus showing the most significant selectivity for facial motion. Our results suggest that monkeys and humans share similar neural substrates within the anterior STS for the processing of facial motion.

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36.4095 **Predictability does not generate or modulate category-selective processes in fast periodic visual stimulation streams**

Genevieve Quek[1](genevieve.lauren.quek@gmail.com), Bruno Rossion[1]; [1]Institute of Research in Psychology (IPSY) & Institute of Neuroscience (IoNS), Université catholique de Louvain

Fast periodic visual stimulation (FPVS) combined with electrophysiological measures of brain activity can fundamentally advance the study of visual perception (Rossion, 2014). Where traditional visual stimulation paradigms use temporally isolated stimuli, this approach presents stimuli at a rapid periodic rate (e.g., 12Hz), providing a continuous flow of information in which each forward/backward-masked stimulus is visible for just a single glance. An electrophysiological response to this stimulation can be found at the exact frequency of presentation (i.e., 12Hz) (Norcia et al., 2015). By embedding critical stimuli at fixed intervals within the sequence (e.g., a face every 5 variable nonface objects), we can observe the response to the critical stimulus category at an objectively defined frequency (e.g., 12Hz/5 = 2.4Hz), and thereby directly quantify the visual system's specific response to this stimulus type. An important issue that we address here is how visual periodicity – which implies predictability - may modulate/generate the response to a critical stimulus. In 18 observers, we compared EEG responses in both the frequency and time-domain for faces appearing periodically or nonperiodically in a fast sequence of natural object images. The robust face-selective response, comprised of four distinct spatio-temporal components over the occipito-temporal cortex, is indistinguishable at the global level for periodic and randomly appearing faces. In a second experiment carried out on 13 observers, following a period of entrainment, rare omissions (10%) of periodic faces do not generate any face-selective response. Thus, overall, we find no evidence of "pre-coding" for faces that are highly temporally predictable: periodicity itself does not generate or drastically alter the profile of face-selective responses – showing that these responses cannot be generated by purely top-down processes.

36.4096 **Cortical arousal signals are actively read out by a face processing system to evaluate the duration of gaze**

Nicola Binetti[1](nicolabinetti@gmail.com), Charlotte Harrison[1], Isabelle Mareschal[2], Alan Johnston[1,3,4]; [1]Department of Experimental Psychology, University College London, UK, [2]School of Biological and Chemical Sciences, Psychology, Queen Mary University of London, UK, [3]CoMPLEX, University College London, UK , [4]School of Psychology, University of Nottingham, UK

Gaze plays a fundamental role in regulating interpersonal interactions. Although many studies have investigated the brain mechanisms responsible for estimating gaze direction, gaze duration is equally important. In this study participants (N=10) were asked to compare the duration of direct and averted gaze shifts performed sequentially by two avatar face stimuli. While performing this task we recorded changes in pupil diameter during both duration encoding and decisional/response selection phases. Previous studies have shown that arousing stimuli lead to longer estimates of elapsed time (e.g. by comparing frightening Vs neutral stimuli). These studies however confound sensory differences in the stimuli, with differences in their arousing effects. We compared pupil responses within a standard binary choice duration discrimination psychophysical paradigm. Pupil size measurements, known to reflect variations in cortical arousal, were grouped on trials in which the standard and comparison stimuli were identical, on the basis of which interval was judged "longer" vs "shorter". This approach enabled us to directly evaluate how differences in cortical arousal (within identical stimuli) are linked to different perceptual outcomes. We observed, during the time encoding phase, that "longer" responses were associated with greater increases in pupil dilation/arousal (direct gaze "longer" Vs "shorter": p=.003; averted gaze "longer" Vs "shorter"=p.02). This time encoding dissociation was only observed in the subsecond range of durations. This pattern of results were not replicated when timing equivalent phase shifts of Gabor stimuli, indicating the difference is face processing dependent. In both datasets however we observed a positive relationship between task difficulty and rate of pupil increase during the decisional/response selection phase (harder Vs easier trials: p=.04). These results demonstrate that endogenous arousal signals are actively exploited by a face processing system (opposed to passively affecting a generic timing system) to encode the duration of gaze shift information.

36.4097 **The Mechanism of Lateral Gaze Bias for Faces**

Bruce Bridgeman[1](bruceb@ucsc.edu), Hema Kopalle[1], Lisa Clark[1], Nicolas Davidenko[1]; [1]Department of Psychology, University of California, Santa Cruz

In viewing faces, Left Gaze Bias (LGB) is a tendency to look at the right side of faces (looking left to see the right side). Two possible mechanisms for the bias are a fixed face-oriented visual exploration strategy, possibly centered in the Fusiform Face Area (FFA) or other right-hemisphere centers, or bias by the 'online' scanpath algorithm that drives all other visual exploration sequences. While both possibilities predict a LGB, they make different predictions for left-right reversed faces. The FFA strategy predicts no change in fixation bias, while the scanpath alternative predicts a right-gaze bias to the extent that the right side of a normal face is more informative. We showed 42 faces from a standard image database to 52 observers, half reversed across their vertical midline axis, and measured visual fixations with an eye monitor that superimposes gaze position on the image. A centered fixation cross was replaced by a face image when fixation was achieved. 73% of our observers showed a left bias for normal faces in the first lateral saccade. On left-right reversed faces, 50 observers showed the same bias as for normal faces, while 2 changed their bias. This clear evidence for the FFA strategy reflects an endogenous origin for first gaze. Subsequent to the first fixation, observers began exploring the other side of the face after a few fixations, indicating that the endogenous bias gives way to a more normal scanpath. Observers were generally unaware of their gaze biases, and a test with a different sample of observers from the same population showed no ability to distinguish normal from reversed faces with a forced-choice behavioral measure. In conclusion, observers show an unconscious bias to saccade first to a preferred side of a face, whether normal or left-right reversed, and later explore both sides.

Face Perception: Wholes, parts, configurations

Sunday, May 15, 2:45 - 6:45 pm

Poster Session, Pavilion

36.4098 **The Influence of Facial-Feature Correlations on Face Perception**

Carl Gaspar[1](ccbd.gaspar@yahoo.co.uk); [1]Center for Cognition and Brain Disorders, Hangzhou Normal University, China

One interpretation of holistic processing is that experience with faces leads to an interdependence of facial-feature appearance. But what would this perceptual interdependence be based on? Can we expect, on average, thick lips when we see round eyes? Here, we ask whether correlations between the top (brows and eyes) and bottom (nose and mouth) of the face are reliable and salient enough for observers to make explicit judgements about the match between the top- and bottom-halves of an unfamiliar, but own-race face. Two experiments used wavelet-based features that greatly diminished textures surrounding feature boundaries. All observers and all stimuli were native Chinese. The 'shape' experiment tested the accuracy of discrimination between faces composed of false and true combinations (bottom-halves were drawn from the same face). 12 observers judged 200 pairs of faces each. An 'adjust-and-match' paradigm ensured that abnormalities in the false combinations were absent, and that shape was critical. Prior MDS testing ensured high perceptual distinctiveness between each top-half. Binomial tests show only 3 subjects chose true-faces above chance. But strangely, half the subjects (6) incorrectly selected false-faces significantly beyond chance. The 'size' experiment measured the precision with which a face top could be manually scaled to match the size appropriate for a fixed-size bottom (8 observers), or vice versa (3 observers). Overall size, and the relative size and position of the adjustable half were randomized. Precision analysis compared true and adjusted log-distances: 10 different upper-face, or 5 different lower-face values. Scaling precision was measured by the mean distance along the 2nd principal component. Precision was impressive: 7 of the 11 observers had a precision less than the minimum predicted by any of our 50 top-to-bottom distance ratios.

36.4099 **Making Spatially Distorted Faces Right: The Effects of Familiarity and Orientation.** Nick Donnelly[1](nd5@soton.ac.uk), Natalie Mestry[1]; [1]Psychology, University of Southampton

Sandford and Burton (2014, Cognition) asked participants to rescale faces to normal after being initially presented with faces of distorted proportions. The important and surprising result was that participants were better at normalising unfamiliar faces compared to familiar faces. They suggested this was due to an increased tolerance to distortion with familiar faces: a result interpreted as questioning the role of relational information in familiar face recognition. We repeated the experiment but had participants first rate for familiarity on a 7-point scale our set of faces. For each participant, only faces rated as very familiar (7) or not familiar at all (1) were included in analysis, though all participants viewed all faces in rating and normalising tasks. In addition to manipulating familiarity (familiar or unfamiliar), orientation (upright versus inverted) was also manipulated. The results showed independent effects of familiarity and orientation on rescaling error. Specifically, rescaling error was lessened when faces were familiar and upright though familiarity and orientation did not interact. In contrast to Sandford and Burton, the data we report are consistent with representations of familiar faces including relational information that allows judgement of overall face proportions. We consider the reasons for our study not replicating the results of Sanford and Burton. In the present experiment, participants were both more practised than in the original study and a consideration of personal familiarity had been raised through performing the rating task.

36.4100 **Misperceived emotion increases the holistic representation of ostensibly neutral faces** Richard Cook[1](Richard.Cook.1@city.ac.uk), Katie Gray[2]; [1]Department of Psychology, City University London, UK, [2]School of Psychology and Clinical Language Sciences, University of Reading, UK

Sequentially presented face halves are harder to match when target halves are aligned with task-irrelevant distractor halves, than when target and distractor halves are misaligned. This composite face effect is thought to be a product of holistic processing whereby information from disparate facial regions is integrated into a unified percept. Previous findings suggest that the presence of expressed emotion induces strong fusion of upper and lower composite halves. However, it is not always easy to distinguish a stranger's permanent facial shape from their transient facial expressions; whether, for example, an unfamiliar actor is scowling or simply has narrow eyes. The present study sought to determine whether misperceived emotion cues influence the strength of composite interference induced by ostensibly neutral faces, in the absence of expressed emotion. In Experiment 1 we examined the relative ability of fifty distractor halves to bias observers' perception of four target halves. The results indicate reliable inter-distractor differences in the strength of illusory bias induced, that correlate with ratings of misperceived emotion awarded by different participants. In Experiment 2 twenty participants completed a sequential matching composite task. Critically, half of the distractor halves were rated high for misperceived emotion, half were rated low for misperceived emotion. While significant composite effects were seen in both conditions, greater modulation was induced by the distractor halves in the high emotion condition. In Experiment 3 we show that composite effects estimated for twenty observers using a well-known variant of the composite face procedure are also strongly influenced by misperceived emotion. These convergent results suggest that misperceived emotion increases the strength of composite fusion induced by emotionless faces. These results have important implications for our understanding of holistic face processing in typical and atypical populations.

36.4101 **Does Holistic Crowding of Faces Depend on Task Demands?** Alex Dayer[1](adayer@ilstu.edu), Kassandra Lee[1], Stephen Chow[1], Eli Flynn[1], Amrita Puri[1]; [1]Illinois State University

Visual crowding is the impairment in peripheral object recognition due to clutter. Recent work has suggested crowding occurs not only between low-level features of stimuli, but between higher-level, holistic representations as well. Inverting the surrounding or flanking faces reduces the effect of crowding, suggesting a holistically-driven interference that contributes to the crowding observed with upright face flankers. However, it is not yet clear whether this flanker inversion effect is specific to faces or generalizes to other object categories. In a series of experiments, we asked participants to perform a discrimination task on either faces or cars, presented in the form of two-tone "Mooney" images lacking readily identifiable parts. Targets were presented at varying eccentricities, either alone or surrounded by upright or inverted flankers. Crowding was observed in the periphery for both types of stimuli in all experiments. In one experiment, we replicated the face flanker inversion effect when participants performed a gender discrimination task on face targets. In another experiment, we did not find an inversion effect for a left-right orientation discrimination task on car targets. Because the lack of an inversion effect for cars could be attributed to differences between task demands, a third experiment assessed crowding of both faces and cars using the same left-right orientation discrimination task. We observed the inversion effect for faces in the gender discrimination task, but found no inversion effect for either faces or cars during the orientation-discrimination tasks; therefore, our results suggest that crowding between holistic face representations may occur selectively for tasks that rely on holistic processing. Additional experiments involving tasks that engage holistic as opposed to strictly part-based mechanisms for processing of non-face objects are necessary in order to determine whether interference between higher-level representations is unique to faces.

36.4102 **The Benefits and Costs of Holistic Processing in Familiarity-Based Associative Recognition for Faces.** Mitchell Meltzer[1](mam362@gmail.com), Gowtham Ganesan[1], Michelle Min[1], James Bartlett[1]; [1]School of Behavioral and Brain Sciences, The University of Texas at Dallas

Much evidence supports holistic processing of faces, but the role of such processing in long-term memory for faces remains unclear. A prior study (Meltzer et al., VSS, 2015) reported evidence that holistic processing supports familiarity-based memory for relations among facial parts or regions. The authors found that with upright faces, thought to be processed holistically, faces containing parts in a previously seen configuration (intact faces) were more familiar to participants than faces containing parts in a novel configuration (conjunction faces). By contrast, they found that with faces that were both inverted and misaligned, participants discriminated intact items from conjunction items partly by recollecting the configurations in which they had previously seen individual face parts. Here, we sought to understand how holistic processing leads to familiarity-based associative recognition for faces. Specifically, we tested the possibility that holistic processing impairs independent recognition of face parts, which could prevent participants from recollecting the context in which they previously saw those parts. Participants studied a list of faces and then took a recognition test containing intact, conjunction, and new faces. For each test face, they judged whether they had seen its top part before, whether they had seen its bottom half before, and whether they had seen the whole face before. Consistent with the holistic-familiarity hypothesis, an ROC analysis suggested that associative recognition judgments made by participants in the upright condition were more familiarity-based than those made by participants in the inverted, misaligned condition. By contrast, participants in the inverted-misaligned condition were better at recognizing the halves of conjunctions they had rejected as wholes than participants in the upright condition. These results, along with those of a follow-up investigation, suggest that holistic processing causes new faces composed of old parts to be perceived as globally unfamiliar by impairing independent recognition of face parts.

36.4103 **The holistic processing of emotional faces in a single and multiple faces** Jisoo Sun[1](js.sun727@gmail.com), Sang Chul Chong[1, 2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Previous studies showed that people could discriminate facial expressions of emotions without accessing to parts of a face (Derntl, Seidel, Kainz, & Carbon, 2009), and also discriminate the mean emotion of a group without accessing to emotions of its members (Haberman & Whitney, 2007), indicative of the holistic processing of emotional faces. The current study investigated whether a single face and multiple faces share the same holistic processes using the face inversion effect, which is known to disrupt the holistic processing (Farah, Tanaka, & Drain, 1995). More specifically, we hypothesized that if emotion judgments of a face and mean emotion judgments of multiple faces share the same holistic processes, face inversion should disrupt both judgments to a similar extent. To test this hypothesis, we used the method of constant stimuli in an emotion discrimination task: An emotionally neutral face was presented in an upright orientation as a standard stimulus. Different degrees of happy or angry faces were shown as comparison stimuli, which could be a single face or four faces in an upright or inverted orientation depending on a block. In each trial, the standard and comparison stimuli were presented on each hemifield. Participants were asked to judge whether the comparison face(s) had a higher emotional intensity than the standard face. We found that the face inversion disrupted the intensity judgments of the emotions when a single comparison face was presented. However, the face inversion did

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not disrupt the intensity judgments of the emotions when the multiple faces were presented. These results suggest that the holistic processing of a single emotional face is different from that of multiple emotional faces.

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36.4104 **Holistic Processing of Unfamiliar Line Patterns** Mintao Zhao[1](mintao.zhao@tuebingen.mpg.de), Isabelle Bülthoff[1]; [1]Department of Human Perception, Cognition, and Action, Max Planck Institute for Biological Cybernetics

Holistic processing—the tendency to perceive objects as indecomposable wholes—has long been viewed as a process specific for faces or objects-of-expertise. While some researchers argue that holistic processing is unique for processing of faces (domain-specific hypothesis), others propose that it results from automatized attention strategy developed with expertise (i.e., expertise hypothesis). While these theories differ in what causes holistic processing, they share a fundamental constraint for its generalization: Non-face objects cannot elicit face-like holistic processing in the absence of expertise. Contrary to this prevailing view, here we show that line-patterns with salient Gestalt information (i.e., connectedness, closure, and continuity between parts) can be processed as holistically as faces without any training. This face-like holistic processing of non-face objects also occurred when we tested faces and line patterns in different sessions on different days, suggesting that it was not due to the context effect incurred by testing both types of stimuli within a single session. Moreover, weakening the saliency of Gestalt information in line patterns reduced holistic processing for these stimuli, indicating the crucial role of Gestalt information in eliciting holistic processing. Taken together, these results indicate that, besides a top-down route based on expertise, holistic processing can be achieved via a bottom-up route relying merely on object-based information. Therefore, face-like holistic processing can extend beyond the domains of faces and objects-of-expertise, in contrary to current dominant theories.

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36.4105 **How Perceptual Similarity Modulates Holistic Processing of Face Composites: Evidence from the Complete Design.** Chao-Chih Wang[1](ccu.gary@gmail.com), Gary Shyi*[1,2]; [1]Department of Psychology and Center for Research in Cognitive Sciences, National Chung Cheng University, Chia-Yi, Taiwan, [2]Advanced Institute of Manufacturing with High-tech Innovations (AIM-HI), National Chung Cheng University, Chia-Yi, Taiwan

Face composite task has been one of the most prevalent research paradigms to demonstrate holistic processing of upright faces. Many researchers examined the exact mechanism underlying holistic processing, but holistic processing and its representation still remain elusive and controversial, some studies have suggested that holistic processing may not be evenly distributed in that processing the top-half of a face might induce stronger holistic processing than processing its bottom-half counterpart. However, the previous studies may have suffered from inadequate control of perceptual similarity between the top and bottom parts of face stimuli. In the present study, we manipulated independently perceptual similarity between the relevant (top) and irrelevant (bottom) parts of face stimuli, such that the relevant part of high versus low similarity were joined by the irrelevant part of high versus low similarity to form composite faces. Participants were asked to judge whether relevant parts of two composite faces were the same or different in a complete design. The results revealed that when the irrelevant parts were of low similarity, holistic processing as indexed by congruency effect was stronger than when irrelevant parts were highly similar. In contrast, whether or not the relevant parts were of high or low similarity, comparable levels of holistic processing were obtained. Taken together, these findings suggest that perceptual similarity, especially of the irrelevant parts, can modulate holistic processing of composite faces. Moreover, previous findings claiming asymmetry of holistic processing between top and bottom parts may be attributed to differences in perceptual similarity of the specific face stimuli that were used.

36.4106 **Does shrinking the perceptual field of view affect horizontal tuning in upright face identification?** Vincent Barnabé-Lortie[1](vincent.b.lortie@gmail.com), Gabrielle Dugas[2], Jessica Royer[2], Justin Duncan[2,3], Caroline Blais[2,4], Daniel Fiset[2,4]; [1]School of Electrical Engineering and Computer Science, University of Ottawa, [2]Département de Psychologie et de Psychoéducation, Université du Québec en Outaouais, [3]Département de Psychologie, Université du Québec à Montréal, [4]Centre de Recherche en Neuropsychologie et Cognition

The face inversion effect (FIE) is characterized by an important drop in recognition performance when facial stimuli are rotated by 180° in the picture plane. Pachai and coll. (2013) showed that inversion disrupts the processing of horizontal information (see also Goffaux & Dakin, 2010) and reported a significant positive correlation between horizontal tuning and the magnitude of the face inversion effect. Recently, Van Belle & Rossion (2015) showed that face inversion reduces the size of the perceptual field of view (PFV). This offers an elegant explanation for the performance drop with inverted faces since a small PFV restricts feature extraction to only a few (maybe one) at a time; a proposition reminiscent of the holistic hypothesis. To make the link between the lack of horizontal tuning with inverted faces and the PFV hypothesis, we measured orientation tuning in five participants for upright faces presented either through a small aperture (a gaze-contingent approach), or as a whole. First, the participants were asked to learn the face-name association for 10 identities. They practiced in each condition until they reached an accuracy of 95%. In the second phase, images were randomly filtered in the orientation domain with orientation bubbles (Duncan et al., 2014) to precisely reveal orientation utilization. Participants performed 400 trials per condition. The signal-to-noise ratio was adjusted so that the same performance level (55%) was obtained in both conditions. Congruently with what was observed for FIE, the signal-to-noise ratio was significantly higher when faces were presented through a small aperture than as a whole [$t(4) = 12.9$, $p < 0.001$]. Despite this large effect, the small aperture condition is not linked to a decrease in horizontal tuning. Our results show that the smaller PFV associated with the FIE cannot explain the lack of horizontal tuning with inverted faces.

Acknowledgement: NSERC

36.4107 **Interaction between social categories in the face composite task** Wenfeng Chen[1](chenwf@psych.ac.cn), Naixin Ren[1], Andrew Young[2], Chang Hong Liu[3]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, [2]Department of Psychology, University of York, [3]Department of Psychology, Bournemouth University

The face composite task (Young, Hellawell & Hay, 1987) is widely considered to be one of the key techniques for demonstrating holistic perception of faces (Rossion, 2013). In the face composite paradigm, parts from different faces (usually the top and bottom halves) are recombined. The principal criterion for holistic perception is that responses involving the component parts of composites in which the parts are aligned into a face-like configuration are slower and less accurate than responses to the same parts in a misaligned (not face-like) format. This is taken as evidence that seeing a whole face in the aligned condition interferes with perceiving its separate parts. However, it remains unclear to what extent the composite effect reflects the presence of a holistic representation of the composite in the aligned condition, or a problem in selectively attending to the parts of this holistic representation (Richler, Tanaka, Brown & Gauthier, 2008). In most studies, these differing potential contributory factors are indistinguishable. Here, we present a new method involving composites created from top and bottom parts of familiar faces drawn from orthogonal social categories of gender and occupation. This allows us to examine the selective attention hypothesis by measuring whether variation in a task-irrelevant category (for example differences in gender across the parts of the composite when the task is to categorise the occupation of one of the parts) will influence the size of the composite effect. Our findings show that the composite effect can be modulated by task-irrelevant social categories, demonstrating the contribution of problems in selectively attending to constituent parts of the aligned composite stimuli.

Acknowledgement: National Natural Science Foundation of China (31371031)

36.4108 **A parametric approach to face drawing studies** Jennifer Day[1](jeaday@ucsc.edu), Nicolas Davidenko[1]; [1]Psychology Department, UC Santa Cruz

We present an extension of the multidimensional face space based on face silhouettes (Davidenko, 2007, 2009) to include front-view faces. The front-view face space was constructed by manually placing 85 identifiable keypoints on the outline and features of 190 front-view faces compiled from 4 different databases. The coordinates of the keypoints were normalized and entered into a principal components analysis to produce orthogonal dimensions that capture the variability of front-view faces. We confirmed the validity of these face stimuli with a celebrity recognition task. In two drawing studies, we tested naive observers' ability to draw these parametric faces. In

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Study 1, 15 participants copied 8 upright and 8 inverted faces (in semi-randomized order) using a stylus on a touch screen, with 90 seconds to copy each face. The accuracy of each drawing was assessed by manually placing 85 keypoints on each drawing and measuring pairwise distances from the corresponding 85 keypoints on the original stimuli. We found that, contrary to common conception, participants were significantly more accurate when copying upright faces than inverted faces, suggesting holistic processing may actually aid, rather than hinder, face drawing. In Study 2, we compared 11 participants' ability to copy a face and then draw the same face from memory. Surprisingly, error rates did not differ significantly between the copying and memory conditions, demonstrating that observers are able to accurately draw parameterized faces from memory. We discuss implications of these findings for improving methods of eyewitness face reconstruction.

36.4109 **Attending to race (or gender) does not enhance adaptation to race (or gender)** Chan Vu[1](chanqvu@gmail.com), Nathan Heller[2], John Collins[3], Nicolas Davidenko[4]; [1]Psychology Department, UC Santa Cruz, [2]Psychology Department, UC Santa Cruz, [3]Psychology Department, UC Santa Cruz, [4]Psychology Department, UC Santa Cruz

Recent research has shown that attention can modulate the strength of face aftereffects. For example attending to changes in facial features increases the strength of identity and figural aftereffects relative to passive viewing (Rhodes et al. 2011). Here we ask whether attending to a specific social dimension of a face influences the strength of face aftereffects in that dimension: specifically, does attending to race (or gender) increase the strength of race (or gender) aftereffects? Across three studies participants (153 UC Santa Cruz undergraduates) observed computer-generated adapting faces that were either unambiguously European and male, or Asian and female for 5 seconds, while instructed to focus on either the race or gender of the face (see Figure 1). In Study 1 (N=45) an intermediate question followed each adapter, soliciting a rating of the attended dimension (e.g. race). In Study 2 (N=68) only half of the trials included this intermediate question, and in Study 3 (N=40) only one quarter of the trials did. In all three studies participants were subsequently presented with a neutral face and asked to rate it on either the attended dimension (e.g. race; congruent trials) or the unattended dimension (e.g. gender; incongruent trials) using a 7-point scale. Overall, participants showed significant aftereffects for both gender and race, manifesting as higher female ratings of the neutral faces following male vs. female adaptors and higher Asian ratings of the neutral faces following European vs. Asian adaptors. Intriguingly, although the attention manipulation influenced reaction times (with lower reaction times on dimension-congruent vs. dimension-incongruent ratings; see Figure 2), attending to race (or gender) did not increase the magnitude of the aftereffect on race (or gender; see Figure 3). Our results suggest that adaptation to a social facial dimension is not enhanced by attending to that dimension.

36.4110 **Global perception of gaze direction across time** Timothy Sweeny[1](timothy.sweeny@du.edu), Diana Mihalache[1]; [1]Department of Psychology, University of Denver

Face perception is emergent. That is, when facial features are seen simultaneously, they are integrated and perceived as a unified whole rather than as disconnected parts. Facial features, however, are sometimes experienced sequentially. Is this emergent process flexible enough to operate in situations like these, integrating constituent features not just across space, but also across time? Alternatively, does seeing features across time disrupt or even prevent this integration? Here, we found that the global perception of another person's gaze direction, which requires integration of head and pupil rotations, can occur even when these features are seen sequentially. Observers viewed a rotated head (without eyes) for 100-msec, 1-second, or 7-seconds. Then, observers indicated the perceived gaze direction of a pair of rotated pupils shown for just 150-msec. Seeing a rotated head attracted the perceived gaze direction of a pair of pupils seen a moment later. For example, observers perceived a pair of eyes with a direct gaze as rotated to the left when they appeared after a head with this same rotation. Surprisingly, this integration persisted even when the head and eyes were separated by delays of up to 1 second, albeit to a weakened extent, suggesting a contribution from visual short term memory (VSTM). Furthermore, prolonged perception of head rotation and associated adaptation further reduced integration. These findings suggest that the visual system strikes a balance between integrating associated face parts and distinguishing between these unique features over time.

36.4111 **Perceived size of the face and arm depends on visual orientation** Sarah D'Amour[1](saod16@yorku.ca), Laurence Harris[1]; [1]Centre for Vision Research, York University

The perception of body size has traditionally been studied using subjective, qualitative measures that assess only one type of body representation - the conscious body image. Previous research has typically focused on measuring the perceived size of the entire body rather than individual body parts, such as the face and arms. Here, we present a novel psychophysical method for determining perceived body size that taps into the implicit body representation. Using a two-alternative forced choice (2AFC) design, participants were sequentially shown two life-size images of either their own arm or their own face. In one interval either the horizontal or vertical dimension of the image was varied using an adaptive staircase, while the other interval contained the full-size, undistorted image. Participants reported which image most closely matched their own perceived size. The staircase honed in on the distorted image that was equally likely to be judged as matching their perception as the accurate image, from which the perceived size could be calculated. The visual orientation of the image was varied to compare performance for familiar and unfamiliar views. When the face was viewed upright or upside down, the width was overestimated and length underestimated whereas perception was accurate for the on-side view. Arm length was significantly overestimated when shown in either horizontal or vertical orientations. These results indicate that participants' representation of their face is wider and shorter than actual size and that they represent their arms as longer than actual size, although of accurate width. The method reveals distortions of the implicit body representation independent of the conscious body image.

36.4112 **Telling people apart and telling people together with face and body information** Hannah Pearson[1](hannah.i.pearson@ndsu.edu), Benjamin Balas[1,2]; [1]Psychology Department, North Dakota State University, [2]Center for Visual and Cognitive Neuroscience, North Dakota State University

Person recognition depends on "telling people apart," and "telling people together" (Andrews et al., 2015). Observers must be able to determine that images of different people depict different identities and also that different images of the same person do not. Observers do this well with segmented and well-controlled images, but perform far worse with natural images. In particular, observers frequently label different images of the same person as different identities in an unconstrained card sorting task (Jenkins et al., 2011) - a failure to "tell people together." Presently, we investigated how both aspects of person recognition function when observers sort naturalistic faces and bodies in isolation, or presented together, for person recognition. We recruited 40 participants to sort multiple images of four unfamiliar individuals into groups based on identity. Participants were not told how many unique identities were present, and either saw images depicting faces only, bodies only, or a full photo. Across conditions, we examined how many groups participants made and their error rates for putting different people in the same group vs. separating images of the same person. Our participants substantially overestimated the number of identities in all conditions (Nface=18.0, Nbody=13.9, Nfull=15.2), and made significantly more face groups than body groups (p=0.006). While "Same-person/Different-group" error rates did not differ across our three stimulus conditions, "Different-person/same-group" error rates did differ, such that the full-image condition led to a significantly lower error rate than either face (p=0.029) or body sorting (p=0.004) and that body sorting led to a higher error rate than face sorting (p=0.024). This demonstrates that the ability to "tell people apart" differs as a function of face/body presence, but the ability to "tell people together" does not.

36.4113 **Looking eye to eye: Face context and featural fixation modulate early neural markers of face perception** Karisa Parkington[1](kparkington@uwaterloo.ca), Roxane Itier[1]; [1]Department of Psychology, University of Waterloo

The N170 is an early ERP component sensitive to faces, but also to eye fixation within a face context, or to eye regions (i.e., two eyes) presented in isolation. Here we investigated the role of face context by comparing N170 modulations when facial features (left eye, right eye, nasion, nose, and mouth) were fixated within a full face or in isolation. Fixation on the desired feature was continuously enforced using a gaze-contingent eye-tracking procedure. We further assessed the N170 response to a single isolated eye compared to the classically used eye region. The N170 was largest and most delayed when fixated features were presented in isolation compared to in a face context, with the largest difference seen for the mouth. For faces, fixation on the left or right eye elicited the largest N170 response compared to nasion, nose, or mouth fixation, reproducing recent findings. However, for isolated features, the response pattern was more complex and varied with hemisphere. Specifically, the N170 response to an isolated mouth was as large as the response to the left eye in the left hemisphere, but was smaller to the response to the right eye in the right hemisphere. Isolated nose fixation showed the most delayed N170 response in both hemispheres. The isolated eye region yielded a larger and shorter N170 compared to a single isolated eye, irrespective of eye or nasion fixation. These results provide support for different neural mechanisms for facial features in isolation compared to within a full face context, and highlight the importance of featural fixation in modulating early neural responses. These findings also provide novel evidence of increased sensitivity to the presence of two symmetric eyes within the eye region compared to only one eye, consistent with an eye region detector rather than an eye detector per se.

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36.4114 **The face inversion effect in rhesus macaques** Olivia Tomeo[1](olivia.tomeo@nih.gov), Ning Liu[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition/NIMH/NIH

Face perception plays a critical role in social communications and interactions. Given the similarities between monkeys and humans in the neural circuitry underlying social cognition, the rhesus macaque could provide an ideal animal model to study face processing. Although human and monkey neuroimaging studies have demonstrated similar face patch systems, behavioral studies exploring face processing in monkeys have yielded inconsistent results. Here, we sought to clarify face-processing mechanisms by re-examining in macaques the face inversion effect, which refers to difficulty in recognizing inverted faces compared to inverted non-face objects. Head-fixed rhesus macaques were trained to perform an oculomotor delayed match-to-sample (DMS) task. Stimuli were from six categories (faces: macaque, chimpanzee, human and sheep; objects: shoes and cars). Faces were forward facing and emotionless. All stimuli were contrast-normalized and grayscale. Faces were cropped with an oval mask to isolate central face information and exclude peripheral features. Subjects were first trained on the DMS task with simple shapes until achieving 85% accuracy, and then performed the test for each category. Reaction time (RT), accuracy, and eye movement pattern were recorded; the efficiency score (RT/accuracy) was used to account for the trade-off between RT and accuracy. We found that scan patterns were similar when viewing macaque, chimpanzee and human faces but not sheep faces. However, better efficiency scores for recognizing upright stimuli than the inverted ones were only found for macaque and chimpanzee faces but not for human faces, sheep faces or non-face objects. These results revealed a face inversion effect for conspecific (macaque) and heterospecific (chimpanzee) faces, implying that macaques process macaque and chimpanzee faces holistically. Our data support the idea that the effect is specific for stimuli for which the individual has developed expertise. We speculate that the subjects generalized their expertise of monkey faces to chimpanzee faces due to similarity.

Monday Morning Talks

Visual Search: Mechanisms

Monday, May 16, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Krista Ehinger

41.11, *8:15 am* The role of crowding on feature singleton search

Anna Madison[1](amadiso2@illinois.edu), Alejandro Lleras[1], Simona Buetti[1]; [1]Visual Cognition and Human Performance, Psychology, University of Illinois at Urbana-Champaign

Two visual search experiments tested the effects of visual crowding using traditional feature singleton search, by varying the spacing between lure objects and the lure-target similarity. Traditionally, search for a feature singleton has been characterized as being independent of set size and produces flat search slopes < 10 ms/item (Wolfe, 1998). However, recent results from our lab suggest search for a feature singleton has a logarithmic relationship between reaction time and set size that is modulated by the lure-target similarity (Buetti et al., submitted). These results have been interpreted as resulting from the first stage of visual processing that is exhaustive, unlimited-in-capacity and resolution limited. Items sufficiently dissimilar to the target are rejected by stage-one processing and items sufficiently similar to the target are inspected with focused attention. Here we ask if the limitation in resolution is a result of crowding, and what the effect of crowding is in the displays producing these logarithmic search slopes. In two experiments, we tested two possible display arrangements differing in the crowding they produced: in the Grid arrangement, spacing was independent of eccentricity and crowding was likely, whereas in the Concentric arrangement, crowding was minimized by increasing inter-item spacing as a function of eccentricity in accordance with Bouma's Law (Pelli, 2008). The results from both experiments converge on the same pattern of results: reaction times increased logarithmically with set size and the logarithmic slope was modulated by lure-target similarity for both spatial arrangements. Further, in both experiments, the Concentric displays produced faster reaction times than the Grid displays, consistent with an additive effect of crowding on reaction times. No interactions were found. These results provide strong evidence against the argument that crowding is a limiting factor in feature search nor is crowding responsible for the logarithmic nature of the reaction time slopes.

41.12, *8:30 am* Attentional deployment during feature and conjunction searches

Laura Dugué[1,2](laura.dugue@nyu.edu), Alice Xue[3], Marisa Carrasco[1,2]; [1]Department of Psychology, NYU, [2]Center for Neural Science, NYU, [3]Stuyvesant High School, NYC

Background. Feature and conjunction search tasks are widely used to study attentional deployment in space and in time. However, the spatio-temporal behavior of attention in these tasks remains under debate. Are multiple search stimuli processed in parallel or sequentially? Does this differ between these two types of search? If so, how? We used an innovative methodology to estimate the distribution of attention on a single trial basis for feature and conjunction search. Methods. Observers (n=8) performed feature and conjunction search tasks during separate sessions. They had to detect and discriminate a tilted low spatial-frequency grating among 3 similar looking distractors (i.e., vertical gratings in feature, and vertical or high spatial-frequency tilted gratings in conjunction search). After a variable delay, two additional probes (Landolt C's) were flashed at random locations. Performance in reporting the probes was used to infer attention deployment to those locations. Using the approach developed by Dugué et al. (PNAS 2015), we determined the probability of probe report at the most (P1) and least (P2) attended locations on a given trial. Were P1 and P2 equal, we would conclude that attention was uniformly distributed across the four locations occupied by the search stimuli. Otherwise, we would conclude that attention was non-uniformly distributed across the four locations. Results/Interpretations. Our results show that, for both feature and conjunction search, attention was non-uniformly distributed across the four locations. These results rule out a strict parallel/uniform model of attention processing during both the feature and conjunction search tasks. Interestingly, attentional distribution over time depended on the location of the probed stimuli in the visual field. This suggests that attentional distribution is heterogeneous across isoeccentric locations in a manner resembling asymmetries in visual performance at these locations.

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41.13, *8:45 am* Conjunctive Targets are Hard in Visual Search but Easy in Centroid Judgments

A. Nicole Winter[1](wintera@uci.edu), Charles Wright[1], Charles Chubb[1], George Sperling[1]; [1]University of California at Irvine

The visual search literature consistently reports a "pop out" effect for targets defined by a single feature. For such targets, reaction time does not change as a function of display size. When targets are defined by a conjunction of features, however, reaction time increases as a function of display size (e.g. Treisman & Gelade, Cognitive Psychology,1980). Featural attention can also be studied using the centroid paradigm, in which the task is to estimate the center of mass of target items in a display (Sun, Chubb, Wright, & Sperling, Attention, Perception, and Psychophysics, 2015). Performance in the centroid task can be measured using the selectivity ratio (the relative weight of targets versus distractors in subjects' centroid estimations), and efficiency (the lower bound on the proportion of items processed). Method: In two sets of experiments, we compared performance in single-feature and conjunction conditions in both visual search (one target, 3 to16 distracters) and centroid tasks (4 targets, 4 or 12 distracters). The feature dimensions were size and color in Experiment 1 and luminance and shape in Experiment 2. Results: In both experiments, our visual search results replicated previous findings as expected. However, in the centroid task, we found improved performance on the conjunctive size-color conditions compared to the single-feature size conditions in Experiment 1, and improved performance on the conjunctive luminance-shape conditions compared to the single-feature shape conditions in Experiment 2. Conclusion: These centroid results are surprising given the visual search literature, which would seem to predict poorer performance on conjunction conditions compared to single-feature conditions. Rather, the centroid results suggest that it is possible to construct (and deploy over space) effective attention filters for conjunctive targets, and these attention filters for conjunctive targets can be even more effective than attention filters for a single constituent feature of the conjunction.

41.41, *9.00* Stochastic noise decreases the accuracy of distractor rejection in dual- compared to single-target search

Doug Barrett[1](djkb1@le.ac.uk), Oliver Zobay[2]; [1]Department of Neuroscience, Psychology and Behaviour, University of Leicester, Leicester, LE1 9HN, UK., [2]MRC Institute of Hearing Research, University Park, Nottingham, NG7 2RD, UK

Simultaneous search for two targets is slower and less accurate than independent searches for the same two targets. Within the SDT framework, this can be attributed to the division of attentional resources across multiple stimulus sets during search (Palmer, Ames & Lindsey, 1993). The current study used one or two cues to elicit single- and dual-target searches in single-fixation and free view displays. Landholt's Cs were used to group display objects into leftward and rightward facing sets. The angle of separation between the target and distractors in each set was adjusted to observers' 80% correct thresholds during a single-target pre-test at a set size of 1. In Experiment 1, the accuracy of "yes-no" judgements was compared on single- and dual-target searches at set-sizes of 1, 2 and 4. The data revealed a reduction in accuracy consistent with an increase in decision-noise in dual- compared to single-target searches. In Experiment 2, the accuracy and latency of observers' initial fixations in single- and dual-target searches were compared. Fixations on single-target searches were highly selective towards the target. The probability of fixating distractors facing the same way as the target was also significantly higher than for those facing the opposite direction. On dual-target searches, fixations were significantly less accurate then on single-target searches. The probability of fixating leftward and rightward facing distractors was also comparable, indicating competition for selection from both sets of objects during dual-target search. These results suggest the dual-target cost reflects a decrease in the accuracy of distractor rejection when objects in the display are compared against multiple representations in visual working memory.

 See page 3 for Abstract Numbering System

41.15, *9:15 am* **How did you hide my bunny? Using a genetic algorithm to investigate preattentive processing of shape in visual search.** Jeremy Wolfe[1,2](wolfe@search.bwh.harvard.edu), Avigael Aizenman[1], Jungyeon Park[3], Lucas Jurgensen[4], Krista Ehinger[1,5]; [1]Visual Attention Lab, Brigham and Women's Hospital, [2]Depts. of Radiology and Ophthalmology, Harvard Medical School, [3]Hankuk Academy of Foreign Studies, Yonginsi, Korea, [4]Belmont Hill School, Belmont, MA, [5]Dept of Ophthalmology, Harvard Medical School

In visual search tasks, attention is guided by a limited set of attributes (color, size, etc.). Shape is one of those attributes, but our understanding of shape guidance has been restricted to shape features (e.g. line termination and closure) that do not fully describe preattentive shape processing. In an effort explore shape space and to generate new hypotheses about shape guidance, we have used a novel genetic algorithm method. We start with a target and twelve distractors, generated randomly in a radial frequency space defined by 10 radial frequencies each with an amplitude and a relative phase. On each trial, observers search for the target in arrays composed of one of the distractors. Reaction time (RT) is the measure of 'fitness'. To evolve an easier search task, distractors that produce faster RTs survive into the next generation, mate, and have children. To evolve a harder search task, distractors yielding longer RTs survive. Items also 'mutate' at a modest rate. The 30 "genes" are the ten frequencies, amplitudes, and phases. The method works. Eight generations of evolution (~20 minute task) can produce search tasks either much easier or much harder than the starting task. For some targets, these results are easily interpretable in radial frequency space. Easy distractors evolve amplitude X frequency spectra that are dissimilar from the target. Hard distractors evolve spectra that are more similar to the target. However, other targets suggest different rules. For instance, when the target is a rabbit silhouette, the hard distractors do not resemble the target in radial frequency space. Moreover, distractors that make rabbit search inefficient do not look much like rabbits. Inefficient rabbit search may arise when distractors have rabbit 'parts' (oblong body, ear-like structures) even if the whole is quite unrecognizable. The same holds true for other target shapes.

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41.16, *9:30 am* **Do Mutations Effects Reveal the Time-Course of Distractor Suppression or Target Processing?** Ricardo Max[1](ricardo.max@nyu.edu), Hayley Lagroix[2], Vincent Di Lollo[2], Yehoshua Tsal[3], Thomas Spalek[2]; [1]New York University, [2]Simon Fraser University, [3]Tel Aviv University

The reaction time (RT) to identify the orientation of a tilted-line target (two alternative responses) is longer when the target is flanked by incongruent distractors (whose identity is the competing target) than when flanked by neutral distractors. This delay is assumed to reflect distractor interference. Max and Tsal (2015) employed the mutations paradigm to assess the time-course of distractor processing: In each trial, while the target remained unchanged throughout the presentation, neutral distractors were replaced by incongruent distractors at a random time between 8 and 66 ms after onset. Results (Fig. 1): RTs decreased as the duration of the neutral display increased, up to 25 ms. When incongruent distractors appeared after 25 ms or later, RTs matched those in a neutral baseline. We consider two possible interpretations: (a) In neutral displays, the target may have been fully processed within 25 ms, which rendered incongruent distractors presented later than 25 ms ineffectual. (b) The distractors may have been suppressed within 25 ms, thus allowing target processing to continue unimpaired beyond 25 ms. We tested these two hypotheses by presenting the neutral display for periods varying between 8 and 91 ms, followed directly by a pattern mask (###). If targets are fully processed within 25 ms, the masking should impair target identification during the first 25 ms, but not beyond. In contrast, if distractors are suppressed within 25 ms, masking should remain effective beyond 25 ms because target processing would still be underway. Results (Fig. 2): Masking was effective for at least 74 ms after target onset, supporting the distractors-suppression option. Homologous patterns of results emerged with incongruent displays, albeit with a longer timecourse (58 and at least 91 ms for distractor suppression and target processing, respectively). These results have implications for perceptual load theory and for early-selection and late-selection theories.

Object Recognition: Neural mechanisms and models

Monday, May 16, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Irving Biederman

41.21, *8:15 am* **What is actually affected by the scrambling of objects when localizing LOC?** Irving Biederman[1,2](bieder@usc.edu), Eshed Margalit[1], Bosco Tjan[1,2], Manan Shah[1]; [1]Neuroscience, University of Southern California, [2]Psychology, University of Southern California

LOC, an area that has been shown to be critical for shape perception (James et al. 2003), is comprised of the Lateral Occipital Cortex (LO) and the Posterior Fusiform (pFs). It is defined (localized) as the region that shows greater activation when viewing intact objects compared to their scrambled versions (resembling texture). But scrambling a) reduces the familiarity of the objects, b) destroys the integrity of the parts, and c) leaves the relations among the parts undefined. We assessed the potential effects of familiarity, with strict control for low-level features by computer modeling familiar objects (Fig. 1a), such as a chair or a lamp, and then rearranging the relations to produce novel, intact objects (Fig. 1b). By scattering the intact parts (Fig. 1c)—but not breaking them up (as would be done in scrambling)—we could assess whether the effects of scrambling an image (Fig. 1d) can be attributed to the loss of parts, relations, or both, with different effects perhaps localized to different regions of LOC. Novel and familiar objects both yielded equivalent activation throughout LOC which was markedly greater than that produced by scrambling. In LO, intact objects (both novel and familiar) produced equivalent activation to scattered parts, suggesting that this area of LOC does not code interpart relations (Fig. 2). However, greater activation in pFs was evidenced by intact objects compared to scattered parts, suggesting that this region of LOC is sensitive to relations between parts.

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41.22, *8:30 am* **Feature-coding transitions to conjunction-coding with progression through visual cortex** Rosemary Cowell[1](rcowell@psych.umass.edu), John Serences[2]; [1]Psychological and Brain Sciences, University of Massachusetts Amherst, [2]Department of Psychology, University of California San Diego

Evidence from electrophysiological studies in animals suggests that the visual object processing pathway in cortex analyzes incoming information in a staged, hierarchical manner. Neurons in early stages of the pathway are tuned to simple visual features (e.g., a line of a particular orientation) whereas neurons in later stages are selective for increasingly complex stimulus attributes (e.g., a collection of lines corresponding to a complex shape). It is widely assumed that feature-coding dominates in early visual cortex whereas later visual cortices employ conjunction-coding in which whole object representations are different from the sum of their simple-feature parts. However, most electrophysiological and neuroimaging studies have measured only a small span of the cortical hierarchy or manipulated stimulus properties at only one level of visual complexity. No study in humans has simultaneously demonstrated that putative object-codes in higher visual cortex cannot be accounted for by feature-coding and that putative feature-coding in early visual cortex is not equally well characterized as an object-code. We present a novel method that employs multivariate analysis of functional brain imaging data to measure feature-coding and conjunction-coding directly and pit them against each other throughout visual cortex. The results provide the first direct demonstration of a continuous gradient from feature-coding in primary visual cortex to conjunction-coding in inferior temporal and posterior parietal cortices. This novel method enables the use of classifier analyses along with experimentally controlled visual stimuli to investigate population-level feature- and conjunction-codes throughout human cortex.

41.23, *8:45 am* **Both convolutional neural networks and voxel-wise encoding models of brain activity derived from ConvNets represent boundary-and surface-related features** Mark Lescroart[1,3](mark.lescroart@berkeley.edu), Pulkit Agrawal[2,3], Jack Gallant[1,2,3]; [1]Helen Wills Neuroscience Institute, [2]Electrical Engineering and Computer Science, [3]University of California, Berkeley

Convolutional neural networks (ConvNets) have achieved almost human-level performance on object recognition tasks, and voxel-wise encoding models based on ConvNet features yield accurate predictions of human brain activity. This suggests that ConvNets might provide important

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insights into brain function. However, the features derived from ConvNets are difficult to describe or relate to other models, so it is difficult to make inferences about human vision directly from ConvNet models fit to brain data. Here we present a new method for interpreting voxel-wise ConvNet models. We used features derived from a popular ConvNet (AlexNet) to model fMRI responses elicited by a large set of naturalistic movies rendered using computer graphics software. As expected, the AlexNet model accurately predicted brain activity in a separate data set. To interpret the fit models, we determined which AlexNet features were associated with the presence of object boundary contours and large surfaces in the stimulus movies. (Boundaries and surfaces were computed based meta-data in the rendering software.) We find that different subsets of AlexNet features represent boundary contours and surfaces, particularly in intermediate layers of AlexNet. We then selectively deleted AlexNet channels representing either boundary contours or surfaces, and used these reduced models to predict brain activity. We find that deletion of boundary-related features impairs predictions in early and intermediate visual areas, while deletion of surface-related features impairs predictions in scene-selective areas. Thus, our results show that a ConvNet trained to classify images represents boundary- and surface-related features that are also represented explicitly in the human brain. Furthermore, our results suggest that specific ConvNet features could be used to quantify object boundaries and large surfaces in arbitrary stimuli. Our approach provides a general, objective method for leveraging the predictive power of ConvNets to make new discoveries about how features in natural images are represented in the brain.

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41.24, *9:00 am* **What is unique in computational models of object recognition ?** Kandan Ramakrishnan[1](K.Ramakrishnan@uva.nl), H.Steven Scholte[2], Sennay Ghebreab[2]; [1]Intelligent Sensory Information Systems, Institute of Informatics, University of Amsterdam, Amsterdam, The Netherlands., [2]Department of Psychology, Brain and Cognition, University of Amsterdam, Amsterdam, The Netherlands.

A big challenge for cognitive neuroscience is to build and apply models based on theoretical knowledge about the human visual system. Recently computational models, inspired from machine learning/computer vision, are increasingly compared and tested against brain responses. These models are highly complex, for example, Convolutional Neural Networks have 7 (upto 22) layers and HMAX, BoW too have a number of computational layers. To properly understand how the different layers compare against the brain and also the differences between models, we need to determine the unique variance to explain brain responses. In our study we determine the amount of unique variance in brain responses explained by layers of various hierarchical vision models. We acquired BOLD fMRI data from 20 subjects who watched an 11 minute natural movie and employed variation partitioning to explain local BOLD variation. This was done using dissimilarity matrices at different layers of representation for three models : HMAX, BoW and CNN. We found that low-level representations such as SIFT and Gabor uniquely contribute in explaining BOLD activity, suggesting that they capture different representations in the brain. At intermediate levels, most of the explained variance by HMAX is shared with BoW, while BoW explains additional BOLD activity. In addition to the unique variance of HMAX and BoW, CNN layers uniquely explained BOLD variation in higher brain areas. Within models, higher layers of HMAX and BoW add unique variance when compared to their respective low-level features. For more complex models such as CNN, we find that certain CNN layers do not add any unique variance. Overall, our results suggest that analyzing computational models of object recognition on the basis of their unique variance provides a different perspective on how these models capture visual representations in the human brain.

41.25, *9:15 am* **CNNs trained on places and animacy explain different patterns of variance for the same dataset.** H.Steven Scholte[1,2](h.s.scholte@uva.nl), Max Losch[1,2], Noor Seijdel[1,2], Kandan Ramakrishnan[3], Cees Snoek[3]; [1]Brain & Cognition, Department of Psychology, University of Amsterdam, [2]Amsterdam Brain & Cognition, University of Amsterdam, [3]Institute for Informatics, University of Amsterdam

With the rise of convolutional neural networks (CNNs), computer vision models of object recognition have improved dramatically in recent years. Most recent progress in computer vision has been spurred by increasing the number of layers within CNN models (so called 'very-deep' learning models). Just like the ventral cortex in the human brain, CNNs show an increase in receptive field size and an increase in neuronal tuning when moving up the neural or computational hierarchy (DiCarlo et al., 2012). However, from neuroscience we know that the brain processes information not only hierarchically but also in parallel (Kravitz et al., 2013). In the current study, we trained a CNN with an Alexnet type architecture (5 convolutional layers, 2 fully connected layers, 1 softmax layer) using two different image sets (animacy or places). Additionally, we evaluated human brain responses towards 120 images (not used for training the CNNs), containing places and animate and inanimate images using BOLD-MRI. For this, we calculated summary statistics, per image, per layer of the CNN and evaluate to what degree we can explain the between image variance. We observe, using the same images, distinctly different patterns of explained variance for the animate trained networks versus the place and inanimate network. The animate trained network explains variance in the middle and inferior temporal gyrus using information from the top two convolutional layers. The summary statistics from the places-trained network explains variance in a range of visual areas using the second fully connected layers and surprisingly, in the parahippocampal complex using the softmax layer. These results suggest, in congruence with our current understanding of the functional achitecture of the brain, that the brain consists of multiple CNNs but also demonstrate that the mapping of CNN vs brain is complex.

41.26, *9:30 am* **Deep Neural Networks as a Computational Model for Human Shape Sensitivity** Jonas Kubilius[1,2](qbilius@mit.edu), Stefania Bracci[2], Hans Op de Beeck[2]; [1]McGovern Institute for Brain Research, MIT, [2]Brain and Cognition, KU Leuven

Theories of object recognition agree that shape is of primordial importance, but there is no consensus about how shape might be represented and so far attempts to implement a model of shape perception that would work with realistic stimuli have largely failed. Recent studies suggest that state-of-the-art convolutional 'deep' neural networks (DNNs) capture important aspects of human object perception. We hypothesized that these successes might be partially related to a human-like representation of object shape. Here we demonstrate that sensitivity for shape features, characteristic to human and primate vision, emerges in DNNs when trained for generic object recognition from natural photographs. We show that these models explain human shape judgments for several benchmark behavioral and neural stimulus sets on which earlier models mostly failed. In particular, although never explicitly trained for such stimuli, DNNs develop acute sensitivity to minute variations in shape and to non-accidental properties that have long been implicated to form the basis for object recognition. Even more strikingly, when tested with a challenging stimulus set in which shape and category membership are dissociated, the most complex model architectures capture human shape sensitivity as well as some aspects of the category structure that emerges from human judgments. As a whole, these results indicate that convolutional neural networks not only learn physically correct representations of object categories but also develop perceptually accurate representational spaces of shapes. An even more complete model of human object representations might be in sight by training deep architectures for multiple tasks, which is so characteristic in human development.

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Visual Memory: Neural mechanisms

Monday, May 16, 10:45 - 12:15 pm
Talk Session, Talk Room 1
Moderator: Abigail Noyce

42.11, *10:45 am* **Visual working memory training with non-invasive neurostimulation increases low frequency phase synchrony** Kara Blacker[1](kara.blacker@jhu.edu), Dwight Peterson[2], Kevin Jones[3], Marian Berryhill[4]; [1]Department of Psychological & Brain Sciences, Johns Hopkins University, [2]Department of Psychological Sciences, University of Missouri, [3]Department of Neurology, Georgetown University, [4]Department of Psychology, University of Nevada

Visual working memory (VWM) is critical for guiding goal-directed behavior across interruptions such as saccades. Currently, training efforts aimed at improving VWM are expanding to include the use of non-invasive brain stimulation, such as transcranial direct current stimulation (tDCS). One challenge is that the mechanism underlying training and tDCS linked VWM improvements remains unclear. Here, participants completed four training sessions on a challenging VWM task while concurrently receiving tDCS to right frontoparietal sites. Participants were randomly assigned to either the anodal tDCS or sham group. Before and after training, participants per-

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formed the VWM task while undergoing high-density electroencephalography (HD-EEG). The behavioral data revealed a significant session (pre, post) x tDCS group (anodal, sham) interaction revealing greater improvement in the anodal tDCS group compared to the sham group, $F(1,22)=5.01$, $p< 0.05$. This result replicates findings showing that tDCS enhances training effects. To investigate the neural correlates of this effect, we examined the HD-EEG data. Specifically, increases in phase synchrony in the 4-10Hz frequency range are related to enhanced VWM performance. Using the right prefrontal stimulation site as a seed electrode and a nonparametric randomization test, we found a significant session x tDCS group interaction for a cluster of posterior electrode sites, $p< 0.05$. Follow-up tests illustrated that after training, frontal-posterior phase synchrony increased in the anodal group significantly, $p=0.05$, whereas the sham group showed no difference. These results confirm the behavioral benefits of adding anodal tDCS to VWM training paradigms and indicate that this benefit is likely due to increased phase synchrony between frontal and posterior brain regions.

Acknowledgement: NIH 1P20GM103650 NIH R15EY022775

42.12, *11:00 am* Posterior alpha EEG dynamics dissociate visual search template from accessory memory items.

Ingmar de Vries[1](i.e.j.de.vries@vu.nl), Joram van Driel[1], Christian Olivers[1]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam

Current models of visual search assume that the brain maintains an active visual working memory (VWM) representation of what we are currently looking for: the "attentional template". Recent evidence suggests that template memory items can be dissociated from "accessory" memory items in VWM, which do not guide attention because they are needed for later use. However, it remains unclear which electrophysiological mechanisms dissociate between template and accessory memories. Here, we measured EEG of 20 human subjects while they performed a VWM task in which they remembered a lateralized item, followed by an 1800 millisecond delay, and then two consecutive search tasks. The order of the search tasks determined the status of the memory item during anticipation of the first search: the lateralized item was either needed in the first search task (template) or in the second search task (accessory). After the first search a second 1800 millisecond delay followed in which the item that was accessory during the first delay became the visual search template for the second search. Time-frequency analysis showed clear posterior alpha-band (8–14 Hz) lateralization effects during the first delay period, consisting of both local power suppression and reduced parieto-occipital interregional phase synchronization in regions contralateral compared to ipsilateral to the memory item. Importantly, these lateralization effects were stronger when the memory item was a template compared to when it was accessory. In contrast, event-related potential analysis revealed that the contralateral delay activity (CDA) was similar across all conditions. Together, these findings are consistent with the idea that alpha oscillations support a state of increased processing or excitability in task-relevant cortical regions. Our results may thus reflect enhanced cortical prioritization of the memory item when this item has the cognitive status of a visual search template.

Acknowledgement: ERC Consolidator grant (615423) appointed to CNLO

42.13, *11:15 am* Occipital, parietal, and frontal cortices maintain only task-relevant features of multi-feature objects in visual working memory

Qing Yu[1](qing.yu.gr@dartmouth.edu), Won Mok Shim[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College

Previous studies have shown that information held in visual working memory is represented in a broad network of brain regions, including the occipital, parietal, and frontal cortices (Ester et al., 2015). However, less is known about whether and how the mnemonic information in parietal and frontal regions can be modulated by task demand. In our previous work (Yu & Shim, VSS 2015), we demonstrated task-modulated working memory representations in the occipital cortex, and potentially in the parietal and frontal cortices. In the current study, we further examined how the working memory representation of each feature in multi-feature objects was modulated by task and spatial location. On each trial, two colored gratings were presented simultaneously with one in each hemifield. Participants were cued to remember either color or orientation of one of the gratings for 10 s. Using fMRI and a forward encoding model (Brouwer & Heeger, 2009; 2011), we reconstructed population-level, feature-selective tuning responses in occipital, parietal and frontal cortices during memory delay. We found that not only orientation but also color information can be maintained over the delay in early visual cortex as well as higher-order parietal and frontal cortices (e.g., IPS and FEF) when it was cued to be remembered. Furthermore, regardless of whether color or orientation was cued, the remembered, task-relevant feature was represented not only in the contralateral but in the ipsilateral hemisphere as well, suggesting a global spread of the representation of the remembered, task-relevant feature. Conversely, neither the task-irrelevant feature of the remembered object, nor any feature information of the not-remembered object was represented. Taken together, these results indicate that the information of remembered features in occipital, parietal, and frontal cortices can be flexibly modulated by task demand, suggesting a highly selective mechanism of visual working memory that encodes and maintains task-relevant features only.

42.14, *11:30 am* Heterogeneous effects of neuronal ensemble size, tuning, and correlation structure on the decoding of spatial working memory in dorsolateral prefrontal cortex

Matthew Leavitt[1](matthew.l.leavitt@gmail.com), Adam Sachs[2], Julio Martinez-Trujillo[3,4,5]; [1]Department of Physiology, McGill University, [2]Division of Neurosurgery, Ottawa Hospital Research Institute, University of Ottawa, [3]Department of Physiology and Pharmacology, University of Western Ontario, [4]Brain and Mind Institute, University of Western Ontario, [5]Robarts Research Institute, University of Western Ontario

Lateral prefrontal cortex (lPFC) neurons are thought to encode working memory (WM) representations of visual space via sustained firing. Neurophysiological studies of WM typically record from individual neurons, thus we lack an understanding of how larger ensembles of simultaneously-recorded neurons represent WM: we do not know if WM representation fidelity is affected by phenomena that are not measurable in single neurons (e.g. noise correlations– rnoise), nor how WM coding properties scale with the size and composition of neuronal ensembles. In order to investigate these questions, we used microelectrode arrays to record from neuronal ensembles in lPFC area 8a of two rhesus macaques while they performed a traditional oculomotor delayed-response task, and assessed the information content of the ensembles using a linear classifier. We found that: 1: The contents of WM (which of 16 locations is being remembered) can be reliably decoded from ensembles of 30-60 units in a 500ms window from a single trial (mean accuracy = 48%; max = 77%; chance = 6.25%). 2: Units that are "non-selective" (ANOVA for remembered location, $p \geq .05$) can still increase the information content of an ensemble, entirely by altering the rnoise structure. 3: The most informative ensembles are not necessarily composed of the most informative individual units. 4: Removing rnoise can yield inverse effects on the fidelity of WM representations depending on the size and tuning properties of the ensemble (maximum 5% median decoding accuracy improvement, minimum -7.6% median decrease; $p = .002$ and $p < .001$, respectively, Signed rank test). Our results demonstrate the importance of correlated variability in WM representation fidelity in lPFC neuronal ensembles, and that its effects are mediated by the size and composition of the ensemble. However, aggregating single neuron properties does not necessarily predict the properties of larger neuronal ensembles.

42.15, *11:45 am* Divergence and convergence in parietal activity during visual attention and short-term memory

Summer Sheremata[1,2](ssheremata@fau.edu), David Somers[3], Sarah Shomstein[4]; [1]Department of Psychology, Florida Atlantic University, [2]Center for Complex Systems and Brain Sciences, Florida Atlantic University, [3]Department of Psychological and Brain Sciences, Boston University, [4]Department of Psychology, George Washington University

Visual attention and short-term memory (VSTM) are distinct yet inter-related processes. While both tasks require the selection of information across the visual field, memory also requires the maintenance of information across time and distraction. VSTM has been shown to recruit areas within the dorsal and ventral attention networks. However, because these areas have been implicated in the spatial selection, it is important to determine whether overlap of activity simply reflects attention demands common to the two tasks. Therefore, we performed fMRI studies that employed attention and VSTM tasks with identical stimuli and attentional selection demands to ask whether signal amplitude, functional connectivity, and contralateral bias reflect maintenance-specific task demands in these areas. While attention and VSTM activated similar cortical areas, BOLD amplitude and functional connectivity in the parietal cortex differentiated the two tasks. Within the dorsal attention network VSTM, increased BOLD amplitude in IPS1/2 but not FEF relative to attention. In addition, the right angular gyrus, an area of the ventral parietal cortex, showed greater deactivation compared to attention. Task demands also modulated parietal functional connectivity. Compared to the attention task, IPS1/2 was more strongly connected with other fronto-parietal areas and more weakly connected with occipital cortex. This divergence between tasks demonstrates that active maintenance in the presence of distractors is reflected in parietal activity and modulates

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functional connectivity with areas across the cortex. In contrast, both tasks converged on the same pattern of hemispheric asymmetry for spatial processing. A contralateral bias, defined by greater activity for items presented in the opposite hemifield, was stronger in the left than right hemisphere across tasks. Comparable spatial bias across tasks suggests that asymmetries are characteristic of selection processes in IPS. Together these results demonstrate that both parietal activity and parietal functional connectivity can distinguish between VSTM and more general attention processes.

42.16, *12:00 pm* **Frontal lobe contributions to auditory and visual working memory** Abigail Noyce[1](anoyce@bu.edu), Samantha Michalka[2], Nishmar Cestero[3], Barbara Shinn-Cunningham[2], David Somers[1]; [1]Department of Psychological and Brain Sciences, Boston University, [2]CompNet, Boston University, [3]Undergraduate Program in Psychology, Boston University

Human caudolateral frontal cortex (LFC) is often characterized as domain-general or multiple-demand, due to its recruitment in a wide range of cognitive tasks (e.g. Duncan 2010, Fedorenko 2013). However, our laboratory has recently used fMRI to demonstrate that direct contrast of either visual and auditory attention (Michalka 2015) or visual and auditory working memory identifies four discrete sensory-biased attention regions in LFC. Two visual-biased areas, superior and inferior precentral sulcus (sPCS and iPCS) are interleaved with two auditory-biased areas, the transverse gyrus bridging precentral sulcus (tgPCS) and caudal inferior frontal sulcus (cIFS). These four structures can be identified bilaterally in more than 75% of subjects (n = 17) and their locations are stable across tasks (attention or working memory) and over time (>1 year; n = 7). Using fMRI BOLD signal change in visual and auditory working memory, and MVPA classifier accuracy, we compared these four LFC regions to (i) posterior sensory-specific structures in temporal, occipital, and parietal cortex, and (ii) general attention structures including anterior insula and dorsal anterior cingulate. Good classifier performance generally co-occurred with high BOLD activity, which we call "good coding." As expected, posterior structures were modality biased, showing good coding either for auditory or for visual tasks. In contrast, anterior insula and dorsal anterior cingulate showed domain generality, with good coding for both tasks. LFC structures exhibited asymmetry between modalities: visual-biased sPCS and iPCS demonstrated good coding in both visual and auditory working memory, but auditory-biased tgPCS and cIFS only showed good coding in auditory working memory. That is, visual-biased areas demonstrated the domain-general properties that have previously been observed in LFC, while auditory-biased areas were more specialized. These results extend our previous understanding of frontal contributions to attention and working memory, characterizing two distinct, sensory-biased attention networks that play quite different roles in human cognition.

Acknowledgement: CELEST (NSF SMA-0835976), NIH R01-EY022229.

Perception and Action: Walking and the visual field

Monday, May 16, 10:45 - 12:15 pm
Talk Session, Talk Room 2
Moderator: Richard van Wezel

42.21, *10:45 am* **The functional coupling of gaze and gait when walking over real-world rough terrain** Jonathan Matthis[1](matthis@utexas.edu), Mary Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas at Austin

When walking over rough terrain, walkers must gather information about the layout of the upcoming path to support stable and efficient locomotion. In this context, the biomechanics of human gait define the task constraints that organize eye movements when traversing difficult terrain. However, very little is known about gaze patterns while walking outside a laboratory setting. It seems likely that a walker's gaze will be heavily biased towards regions of upcoming terrain around their biomechanically-preferred foothold location, with temporal coupling to the phase of the ongoing gait cycle in a manner shaped by the physical dynamics of bipedal walking. To test this hypothesis, we developed a novel experimental apparatus that records the eye movements and full-body kinematics of subjects walking over real-world terrain. For the first time, we can precisely record gaze and body movement data during natural behavior in unconstrained outdoor environments. Subjects walked over terrain of three increasing difficulties –obstacle-free packed earth paths, moderately rocky trails, and extremely rough dry creekbeds. In flat terrain, subjects spent most of the time looking far down the path and visually exploring their environment. Ground fixations were infrequent and not directed towards future footholds, consistent with the minimal visual information needed to guide foot placement in flat terrain. In contrast, subjects walking over rough terrain displayed strong spatiotemporal coupling between gaze patterns on upcoming terrain and their ongoing gait cycle. In difficult terrain, subjects performed rapid visual search on regions around 2-4 steps ahead, often fixating precisely on locations of upcoming footholds. Saccades between future footholds suggest that nearby steps are selected by balancing between the biomechanically-preferred, energetically optimal step location and the availability of footholds further down the path. Thus the demands of foot placement in real-world terrain leads to more active and flexible gaze patterns than predicted from laboratory-based experiments.

Acknowledgement: NIH-1T32-EY021462 NIH-R01-EY05729

42.22, *11:00 am* **Biomechanical and visual constraints on rapid adjustments to foot placement during continuous locomotion** Sean Barton[1](bartos5@rpi.edu), Jonathan Matthis[2], Evelyn Hinojosa[1], Dylan Brion[1], Brett Fajen[1]; [1]Rensselaer Polytechnic Institute, [2]University of Texas, Austin

To control precise stepping onto a target foothold, walkers use visual information prior to step initiation to modify the ballistic trajectory of the body (Matthis, Barton, & Fajen, 2015). This allows them to capitalize on the energetic efficiency and stability afforded by the pendular structure of the lower limbs. However, it is often necessary to respond to changes in the position of intended target footholds that occur around step initiation. If walkers use visual information to modify their ballistic trajectory in response to perturbations, changes in the trajectory of the center of mass (COM) should be apparent and should occur early in the step. Alternatively, if vision is used to actively guide the foot in a reach-like movement, responses should be localized to the foot and occur later. Twelve subjects walked over a path of lighted foot targets while their movements were recorded by a motion capture system. On some trials, the location of one target in the path was perturbed in one of four directions either before or after step initiation. Analyses of acceleration profiles of the feet and COM revealed that the response depended on both the time and direction of perturbation. When perturbations occurred along the direction of locomotion, changes in COM acceleration were observed early in the gait cycle if visual information was available during the preceding step or near toe-off. Perturbations orthogonal to the direction of locomotion elicited reach-like movements of the foot later in the step, regardless of whether the perturbation occurred before or after step initiation. Walkers use visual information to exploit their pendular structure even when responding to perturbations, but this is dependent on the timing of the perturbation relative to step initiation. Additionally, walkers make reach-like movements with the foot when adapting the ballistic trajectory is untenable.

Acknowledgement: NSF 1431078

42.23, *11:15 am* **Oscillatory Optical Flows Improve the Perception of Travelled Distance in Static Observers** Martin Bossard[1](bossard.martin@gmail.com), Jean-Claude Lepecq[1], Daniel Mestre[1]; [1]Aix-Marseille Université, CNRS, ISM UMR 7287, Marseille, France

When static observers are exposed to a visual simulation of forward self-motion, they generally overestimate travelled distance relative to a previously seen distant target (Redlick, Harris, & Jenkin, 2001). Using the same experimental paradigm, we reproduced this result, which can be accounted for by a "leaky path integration" model (Lappe, Jenkin, & Harris, 2007). However, we also showed that a translational optical flow with "biological" additional oscillatory components, simulating head motion during natural walking, allows for better perception of travelled distance, as compared to a purely translational flow. This result can be discussed as an improvement of path integration, using an "ecological" optic flow pattern (close to "natural walking" feedback). In a subsequent experiment, we tested if it is the biological or the rhythmical nature of the simulation which provides better estimates of travelled distance. Participants were standing and passively confronted to three conditions of virtual simulation of self-motion in a 4-sided CAVE: (1) a translational optical flow (2) a translational flow, with an added rhythmic component, via "triangular" oscillations in the vertical axis and (3) a "biological" flow, reproducing natural motion of the head during walking, as previously measured and modelled using a motion capture system. The results confirm that the addition of rhythmical components in the optic flow pattern improve the accuracy of travelled distance. However, they failed to reveal a significant difference between "biological" and "rhythmic" oscillations. Further experiments on the effect of spatio-temporal oscillatory components in the optical flow are required. However, these results can be related to recent studies comparing the effect of smooth and "jittering" optic flows on vection onset and strength (Palmisano et al., 2014). One suggestion is that oscillatory components produce a non-monotonous pattern of retinal motion, maintaining optimal sensitivity to optic flow, and consequently improving the perception of travelled distance.

42.24, *11:30 am* **Visual information for the joint control of speed and direction in pedestrian following** Gregory Dachner[1](gregory_dachner@brown.edu), William Warren[1]; [1]Cognitive, Linguistic & Psychological Sciences, Brown University

During collective crowd motion, an individual pedestrian coordinates their locomotion with visible neighbors. Previously, we found that an individual matches the walking speed (Rio et. al. 2014) and heading direction (Dachner & Warren 2015) of a neighbor. Here we investigate the visual information that jointly governs speed and heading. We hypothesize that when the neighbor is in front, optical expansion controls speed while change in bearing controls heading direction; but when the neighbor is to one side, these relations reverse. In Experiment 1, participants followed a virtual pole (40cm) that changed speed or direction or both, while the walking trajectory was recorded. We varied the target's direction change (left, no change, right), speed change (decrease, no change, increase), initial position (0° in front, 30° or 60° to the side), and initial distance (1m, 4m). Results show that the follower matched the target's final direction ($F(2,33)=2806.53$, $p< 0.001$) and final speed ($F(2,33)=128.27$, $p< 0.001$). Importantly, other interactions were found. When the target was in front (0˚) and changed direction, the participant only turned ($F(2,33)=1531.41$, $p< 0.001$); but when the target was to the side (60˚), the participant both turned ($F(2,33)=2018.19$, $p< 0.001$) and changed speed ($F(2,33)=121.59$, $p< 0.001$). Moreover, at 0˚ the response delay to speed change was shorter than to direction change, but this relation reversed at 30˚ and 60˚ ($F(2,66)=45.1$, $p< 0.001$). These results are consistent with optical expansion controlling speed and bearing controlling heading when the target is in front, but these reverse when the target is to the side. In Experiment 2, we independently manipulate the target's bearing and expansion. Preliminary results suggest that the effect of optical expansion depends on target position. These findings imply that an individual pedestrian's motion is driven by the visual information that couples them to their visible neighbors. Supported by NSF BCS-1431406

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42.25, *11:45 am* **Visual cues from augmented reality glasses to improve gait of Parkinson's disease patients** Richard van Wezel[1,2](r.vanwezel@donders.ru.nl), Ciska Heida[2], Jorik Nonnekes[2], Yan Zhao[2]; [1]Biophysics, Donders Institute for Brain, Cognition and Behaviour, Radboud University, Nijmegen, [2]Biomedical Signals and Systems, MIRA, University of Twente

External cueing with rhythmic auditory stimuli or patterned visual stimuli reduces freezing of gait and improves the quality of gait in patients with Parkinson's disease (PD). We investigated whether augmented reality glasses can be used to provide these cues and improve locomotion for these patients in a laboratory setting using activities of daily living. We delivered rhythmic visual and auditory cues with the Google glass, such as flashing lights, moving patterns and sounds. Subjects were instructed to navigate different walking paths of varying complexity that included wide and narrow turns and the entrance of a door. The patients were fitted with inertial sensors in a motion capture suit on their body to quantitatively analyze their walking pattern. Two independent raters scored freezing of gait based on videos. The results show that with cues gait patterns normalize and freezing of gait reduces, especially during complicated movements (e.g. full turns, doorways). We conclude that visual/auditory augmented reality cues by smart glasses are a promising tool to reduce freezing of gait and improve the walking patterns of PD patients.

Acknowledgement: NutsOhra

42.26, *12:00 pm* **Sharper, stronger, faster upper visual field representation in primate superior colliculus** Ziad Hafed[1](ziad.m.hafed@cin.uni-tuebingen.de), Chih-Yang Chen[1,2]; [1]Werner Reichardt Centre for Integrative Neuroscience, Tuebingen University, [2]Inernational Max Planck Graduate School of Neural and Behavioural Sciences, Tuebingen University

The primate superior colliculus (SC) is critical for vision, cognition, and motor control. An overwhelming assumption about the SC's anatomical representation of visual space is that it magnifies foveal representations, but equally so for different elevations from horizontal. Here we demonstrate a dramatic and categorical difference in the SC's representation of upper versus lower visual fields. We recorded from 419 visual, visual-motor, and motor-related SC neurons in two macaques. The monkeys performed a variety of standard behavioral tasks, including visually-guided saccades, delayed-visually guided saccades, and memory-guided saccades. Moreover, we mapped neural spatial-frequency tuning curves by flashing a high-contrast (80%) vertical gabor grating of different spatial frequency (0.56, 1.11, 2.22, 4.44, or 1.11 cycles/deg) in receptive fields (RF's). Contrast sensitivity curves were also measured at 2.22 cycles/deg. Our neural database covered a large range of eccentricities (fovea to >20 deg) and directions (-90 to 90 deg from horizontal), allowing us to functionally identify differences between upper and lower visual field representations. We found that SC RF's are much smaller, more finely tuned to image spatial structure, and more sensitive to image contrast in the upper visual field. Stronger upper visual field responses are also faster. Analysis of putative synaptic activity after stimulus onset revealed a particularly categorical change when the horizontal meridian is crossed, and our observations correctly predicted novel eye movement effects. Given the structural implications of smaller RF's on SC topography, we developed an alternative model of afferent and efferent mapping in the SC, which is more accurate than the universally accepted model, and which motivates recasting of structure-function relationships in the visual system in general. Despite its appearance as a continuous layered sheet of neural tissue, the SC contains a functional discontinuity between upper and lower visual field representations, paralleling a physical discontinuity present in cortical visual areas.

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Monday Morning Posters

Development: Lifespan and neural mechanisms

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3001 Abnormal Visual System Connectivity in Human Albinism

Anahit Grigorian[1,2](grig.annie@gmail.com), Larissa McKetton[1,2], Keith Schneider[1,2]; [1]Department of Biology, York University, [2]Centre for Vision Research, York University

Introduction Albinism is an inherited condition caused by mutations in genes involved in melanin synthesis. The lack of melanin results in ophthalmic deficits such as reduced visual acuity and misrouting at the optic chiasm (OC). Structural MRI has revealed narrower OCs and smaller lateral geniculate nucleus (LGN) (McKetton et al., 2014). The number of LGN relay neurons has been linked to LGN volume, suggesting a correlation between LGN size and the number of tracts traveling through the optic radiation (OR) to the primary visual cortex (V1) (Yucel et al., 2000). Using diffusion data and both deterministic and probabilistic tractography, we studied differences in the primary visual pathway between albinism and controls. The medial geniculate nucleus (MGN), an auditory nucleus adjacent to the LGN, was investigated to observe potential compensatory alteration in morphology and connectivity. Methods Patients and controls were scanned using a Siemens Trio 3T MRI scanner and 32-channel head coil. LGN regions of interest (ROIs) were created from multiple registered and averaged proton density weighted images. A T1-weighted 3D-MPRAGE sequence with 1 mm3 isotropic voxel size was used to generate high-resolution images for V1 segmentation. Diffusion tensor imaging (DTI) scans were acquired with 64 diffusion directions. Both deterministic and probabilistic tracking methods were run and compared, with LGN as the seed mask and V1 as the target mask in diffusion space. Mean fractional anisotropy and diffusivity maps of visual structures were compared in both groups. Results Our results reveal areas of significantly reduced white matter integrity within visual structures including the OC and OR in patients with albinism compared to controls. We also observe reduced MGN volumes in albinism compared to controls. Conclusions We have demonstrated altered structural development in visual pathways and possible sensory cross-modal interactions using structural and diffusion MRI.

Acknowledgement: NSERC

43.3002 DTI reveals asymmetry in the optic radiations following early monocular enucleation

Nikita Wong[1](nwong227@yorku.ca), Sara Rafique[1], Krista Kelly[2], Stefania Moro[1,3], Jennifer Steeves[1,3]; [1]Department of Psychology and Centre for Vision Research, York University, Toronto, ON, Canada, [2]Retina Foundation of the Southwest, Dallas, TX, [3]The Hospital for Sick Children, Toronto, ON, Canada

Introduction. Early monocular enucleation (surgical eye removal) results in enhanced visual spatial processing (Steeves et al., 2008) and better sound localisation (Hoover et al., 2012). These behavioural findings are supported by recent neuroimaging studies that demonstrate morphological changes in visual and auditory processing regions, including decreased lateral geniculate nuclei (LGN) volumes, and increased surface area and gyrification in visual, auditory and multisensory cortices (Kelly et al., 2015). Given the existing behavioural and morphological differences following early eye enucleation we investigated how the loss of one eye affects the development of connectivity within the visual system, particularly in the optic radiations. Methods. Participants were scanned using diffusion tensor imaging (DTI) and probabilistic tractography was performed to delineate the optic radiations. Seeds were placed at the LGN with waypoints and termination points in primary visual cortex in order to generate the optic radiations. Tract-based spatial statistics were used to extract the skeletonised fractional anisotropy (FA) values of the reconstructed optic radiations. Mean FA values were compared between individuals who had undergone early monocular enucleation and binocularly intact controls. Results. Unlike controls, people with one eye exhibited a hemispheric asymmetry, with significantly larger FA values in the right optic radiation compared to the left, independent of eye of enucleation. Conclusions. The asymmetry suggests structural changes to the optic radiations in people with one eye. This difference in FA may reflect compensatory changes in the right hemisphere in order to preserve normal function, however, it may also be the result of a deficit in a left lateralised function. Overall, this asymmetry could indicate accommodation for the loss of an eye early in life.

43.3003 Vernier stimuli reveal fellow eye deficits in both early- and higher-level cortex in human strabismic amblyopia

Chuan Hou[1](chuanhou@ski.org), Preeti Verghese [1]; [1]The Smith-Kettlewell Eye Research Institute

Fellow eye deficits in strabismic amblyopia have been demonstrated as early as the P1 component of visual evoked potential (VEP) responses to illusory contours (Hou et al., 2014), suggesting that these deficits arise in early visual cortex (V1 and V2). As VEP measures of vernier acuity are a sensitive test for amblyopia and faithfully reflect letter acuity measured psychophysically (Hou et al., 2007), we wanted to take the VEP vernier paradigm one step further with EEG source-imaging to localize the cortical sources of fellow eye deficits. High-density VEPs were recorded monocularly in adult strabismic amblyopes who were stereo-blind, as well as age-matched normal vision controls in two vernier paradigms (Fig.1): a swept paradigm that used a range of offsets from 0.5 to 8 arcmin to measure both threshold (vernier acuity) and supra-threshold responses, and a fixed (8 arcmin) supra-threshold vernier paradigm to measure the time course of vernier processing. Consistent with previous neuroimaging studies, we show that the amblyopic eye has reduced vernier acuity in V1 (Fig.1A) and lateral occipital cortex (LOC), and weaker response amplitudes to supra-threshold vernier in both early (V1, V3a, hV4 and LOC) and high-level cortical regions including dorsal and ventral pathways, compared to controls. Surprisingly, the fellow eye has normal vernier acuity in V1 (Fig.1A) and LOC, but significantly reduced responses at supra-threshold vernier offsets as measured by the swept-vernier paradigm. The fixed supra-threshold vernier paradigm also shows delayed and reduced responses in these same areas (V1 and LOC). Furthermore, responses are delayed and reduced in higher-level cortical regions, especially in the ventral form processing regions such as parahippocampal and fusiform cortex, specialized for form processing related to places and faces, respectively. Our results indicate that disruption of normal binocularity affects form processing in both the amblyopic and the fellow eye.

Acknowledgement: The Smith-Kettlewell Eye Research Institute, Pacific Vision Foundation

43.3004 Functional Re-Organization in the Face-Processing Network Across Development

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It is increasingly evident that functional specialization in the brain emerges from interactions between regions in a distributed neural network. However, the understanding of how these functional networks develop is only just emerging. We evaluated how the topology of functional neural networks varies as a function of age while children (5-9 yrs), younger adolescents (YA: 10-14 yrs), older adolescents (OA: 15-18 yrs), and adults (19-35 yrs) observed dynamic movies of human faces, moving objects, buildings and navigational scenes while being scanned using fMRI. Core and extended regions in the face-processing network were defined at the group level and then subsequently fit to each participant's individual activation. To evaluate how functional connectivity is modulated by visual category, we employed a psychophysiological interaction approach by computing the interaction between the timing of the visual category presentation and fMRI timecourse and convolved this interaction with a canonical HRF from each ROI. To determine models of connectivity, these convolved timeseries were submitted to separate unified SEMs for each age group to estimate directional connections among all nodes. We used graph theory metrics to quantify global network topology as well as node (i.e., region) characteristics. Although, there were no group differences in the global network structure during face or object viewing, there were impressive age-related changes in the centrality of the nodes, which reflects the hub-like nature of the individual regions. Specifically, the pattern of directional connections into and out of the right FFA, right OFA, bilateral amygdala, and anterior temporal poles during face processing varied across each age group, resulting in different functional organiza-

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tion throughout the network. These findings reflect age-related functional re-organization of the neural network architecture underlying face processing in the transition from childhood through adolescence and adulthood.

43.3005 Object 3D structure representation is immature in late childhood Erez Freud[1](erezfreud@gmail.com), Marlene Behrmann[1]; [1]Department of Psychology Center for the Neural Basis of Cognition Carnegie Mellon University

One of the most basic and fundamental aspects of visual perception is the ability to extract depth cues and generate 3D representations of our visual surrounding. Previous studies have suggested that this ability is developed early in life, and is already present in infancy. However, considerable evidence suggests that the visual system reaches maturity only in late adolescence. Here, we examined the sensitivity of the visual system to object 3D structure in children aged 7.5-12 years old. In a series of experiments, we showed that children were less sensitive to structural information than adults and that this skill correlated with age. More interestingly, children did not exhibit sensitivity to this type of information even in a task in which patients with ventral temporal lesions and visual object agnosia exhibited such sensitivity. These results suggest that the underlying representations of object 3D structure is not yet mature even in late childhood. Finally, and of interest, we also demonstrated that these representations could be elicited in children when instructed specifically and given practice to engage in depth processing, and this resulted in enhanced sensitivity to structural information. Taken together, the results of the present experiments suggest that the representations of object 3D structure are not yet mature in late childhood and are more prone to be modulated by practice and experimental setting.

Acknowledgement: National Science Foundation

43.3006 Common representational structures across the ventral visual pathway of children and adults Michael Cohen[1](michaelthecohen@gmail.com), Daniel Dilks[2], Jenelle Feather[3], Kami Koldewyn[4], Sarah Weigelt[5], Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Sciences, McGovern Institute for Brain Research, Massachusetts Institute of Technology, [2]Department of Psychology, Emory University, [3]UC Berkeley/UCSF Graduate Program in Bioengineering, [4]Department of Psychology, Bangor University, [5]Department of Psychology, Ruhr-University

How does the functional organization of the ventral visual cortex develop? Most previous studies have concluded that the ventral pathway develops slowly and may take over a decade to fully mature (Golarai et al., 2007; Grill-Spector et al., 2007; Scherf et al., 2007). However, these studies primarily focus on the size and response properties of category-selective regions (e.g., fusiform face area (FFA)). While important, these studies do not shed light on larger-scale representational structures within the visual system. To address this issue, we used representational similarity analysis (Kriegeskorte & Kievit, 2013) to compare the representational structures across the ventral pathways of children and adults. We used fMRI to scan children (ages 5-7, N=39) and adults (N=39) while they viewed videos of faces, bodies, scenes, objects, and scrambled objects. All analyses were carried out in two regions of interest (ROIs): early and ventral visual cortex. Within these ROIs, we correlated the neural activation patterns for each category pairing (e.g., faces and scenes, etc.). This resulted in similarity matrices for each ROI that we then compared across ages by correlating the similarity matrices for each ROI between children and adults. Surprisingly, we found that the similarity matrices between children and adults in ventral visual cortex were nearly identical ($r=0.97$, $p< 0.001$), while the similarity matrices in early visual cortex were also very similar between the two groups ($r=0.84$, $p< 0.001$). However, the correlations between early and ventral visual cortex both within and between age groups were not significant. These findings, along with prior results, together suggest that even though category-selective may take several years to reach maturation, the large-scale structures across the ventral pathway have already developed by 5-7 years old. These results suggest that large-scale structures develop early and serve as a foundation upon which category-selective regions are built.

43.3007 Age-related differences of perceptual decisions in binocular rivalry Elahe Arani[1](e.arani@gmail.com), Raymond Ee[1,2], Hil Meijer[3], Richard Wezel[1,4]; [1]Department of Biophysics, Donders Institute for Brain, Cognition and Behavior, Radboud University Nijmegen, The Netherlands, [2]Laboratory of Experimental Psychology, University of Leuven, Belgium, [3]Department of Applied Mathematics, Twente University, The Netherlands, [4]Biomedical Signals and Systems, MIRA, Twente University, The Netherlands

Some aspects of decision-making are known to decline with normal aging. To understand how age affects visual decision-making, we investigated age-related changes in perception during binocular rivalry (BR). In BR, the image presented to one eye competes with that presented to the other eye in order to achieve perceptual dominance. Perception during BR consists of alternations between exclusive percepts, however sometimes mixed percepts become more prevalent. In the first experiment, 52 observers, ranging from 17 to 72 years old, viewed rivalry stimuli and they were forced to make a choice between exclusive percepts. Stimuli were presented intermittently for 1 second, with a range of inter-stimulus intervals (0.125 – 2 seconds). The results show that perceptual alternations decrease at an older age. In the second experiment, we instructed 23 subjects divided into two age groups (21.5±3 and 59.3±6.4 years old) to report both exclusive and mixed percepts during the intermittent stimulus representation for the same setting as in experiment 1. In addition to a decline in perceptual alternation rate for the older group, the proportion of mixed percept also decreased for this group. Furthermore, the results show that during sustained exposure to BR stimuli, the proportion of mixed percepts among young and old subjects is not significantly different. These results challenge the hypothesis that older age differences in perceptual decision-making in BR are related to less adaptation and/or less cross-inhibition. To investigate the cause of this aging difference, we used the spiking neural model for BR by Laing and Chow (J. Comp. Neurosci., 2002). Our data and model suggest that differences in gain modulation at the input can simulate the aging aspect of perceptual decisions in BR, and not differences in parameters related to adaptation or synaptic depression.

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43.3008 Do children demonstrate biases in space perception consistent with angular expansion? Anna Scheibmeir[1](ascheib1@swarthmore.edu), Abigail Dean[1], Stella Christie[1], Frank Durgin[1]; [1]Psychology, Swarthmore College

Large biases in the perception of orientation and distance may indicate efficient coding of angular variables. Deviations of surface orientation from horizontal are exaggerated by about 1.5 in perceptual experience: For example, a surface only 34° from horizontal appears to be midway between vertical and horizontal (VH bisection). Perceptual matching of egocentric distance along the ground with vertical height of tall objects also implies a 1.5 gain in perceived angular direction relative to straight ahead. How do these spatial biases develop? We compared young children (4–8 years old; N = 18) and adults (18-21 years old; N = 31) on standard tasks measuring angular expansion: outdoors height/distance matching tasks (pole heights of 5 and 7m), indoors 3D surface VH bisection task, and a similar 2D line orientation VH bisection task. For the indoor orientation tasks, children showed a similar bias as adults in the perception of both surface orientation (~34° = VH bisection) and 2D line orientation (~38° = VH bisection). Similarly, on the outdoor task in which egocentric distance was matched to pole height, the overall mean bias for children was similar to that observed for adults. Interestingly, there was a reliable trend in the data for younger children to show less bias for the 7m pole, $r(16) = .61$, $p = .007$, and a non-reliable trend for the 5m pole, $r(16) = .23$, $p = .356$. Consistent with this trend, for the 7m pole, children 5.5 years or younger showed a smaller bias ($M = 1.36$) than those older than 5.5 years ($M = 1.7$), $t(16) = 3.6$, $p = .002$, although neither bias differed from adults ($M = 1.5$). Overall, perceptual biases in children and adults are consistent with angular expansion suggesting that this form of efficient coding is present early in childhood and is fairly stable into adulthood.

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43.3009 The hemifield independence in multiple object tracking is preserved in healthy ageing Eugenie Roudaia[1](eugenie.roudaia@umontreal.ca), Simon Lacoste[2], Jocelyn Faubert[1]; [1]Visual perception and psychophysics laboratory, Université de Montréal, [2]Department of Psychology, Université de Montréal

Multifocal attentional tracking is characterized by hemifield independence (Alvarez & Cavanagh, JOV, 2015). Whereas the maximum tracking speed declines with the addition of new targets in the same hemifield, it is virtually unaffected by new targets in the opposite hemifield (Holcombe & Chen, Cognition, 2012). Hemifield independence likely relies on a network of competitive inter-hemispheric interactions (Battelli et al., JOCN, 2009). Considering known age-related changes in hemispheric asymmetry and cross-hemispheric communication (Davis et al., Cereb. Cortex, 2012), hemifield independence in attentional tracking may be affected in ageing and may contribute to the observed declines in multiple object tracking in ageing (Sekuler et al., Perception, 2008). We examined the effect of target and distracter laterality on tracking in 11 younger ($M = 24.5$ y.) and 11 older

(M = 68.2 y.) participants. Stimuli comprised pairs of circles centred in one of four quadrants. There were 5 conditions: 2 unilateral targets (left or right), 2 bilateral targets (upper or lower), with and without distracter pairs in the remaining quadrants, and 4 targets (one in each quadrant). On each trial, participants tracked the targets while the circle pairs rotated at a constant speed along circular trajectories (2.5º radius) for 5s. Rotation speed varied across trials according to the method of constant stimuli. As expected, younger participants showed slower thresholds in the unilateral (M = 1.74, SD = 0.39) compared to the bilateral (M = 1.84, SD = 0.35) conditions. This bilaterality advantage was also seen in the older group (bilateral: M= 1.09, SD = 0.76; unilateral: M=0.93, SD = 0.65). There was no significant age by laterality interaction. Distracter pairs had no effect on performance in either group. Finally, thresholds for tracking four targets were the same as thresholds for tracking two unilateral targets in both groups. These results point to preserved hemifield independence in attentional tracking in ageing.

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43.3010 Haptic-visual solid shape matching with variable numbers of fingers

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Thirty-six younger and older adults participated in a cross-modal shape matching task. On any given trial, a participant haptically explored, but could not see, a plastic copy of a bell pepper (Capsicum annuum) for seven seconds; the participant then chose which of 12 simultaneously visible bell peppers possessed the same 3-D shape. Some participants explored the object shapes using only one finger (the index finger), while others used either three or five fingers. Interestingly, there was no effect of the number of fingers upon the participants' shape-matching performance. There was, however, a strong effect of age: the younger adults' performance was 48.6 percent higher than that of the older adults ($F(1, 30) = 15.7$, $p < .001$, partial eta-squared = .34). These results (i.e., no effect of the number of fingers) differ from those of Jansson and Monaci (2004, 2006) who found a large difference in performance between the use of one and three fingers for recognizing mostly manmade objects. When perceiving naturally-shaped objects, it appears that one finger is all that is required for accurate haptic-visual shape matching performance.

43.3011 Reduced attention suppression in old age may explain decline in motor control

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Normal aging is thought to be associated with specific decline in attention mechanisms of suppression (e.g., Schmitz et al., 2010). In particular, we have previously reported (Tzvetanov et al. 2013) reduced suppression in old age in a salience suppression task that has been shown to rely on proactive suppression in the left IPS (Mevorach et al., 2009). The effect of aging has also been documented in the motor control domain (e.g., Seidler et al., 2010) but the link between decline in attention and motor control is still poorly understood. In the present study we investigated the relation between reduced suppression in old age (as in Tsvetanov et al., 2013) and reduced motor control in a simple reaching task. Young and old participants had to reach for a predefined target as quickly and as accurately as possible. In certain blocks of trials distractors also appeared adjacent to the target. In addition, participants also performed a visual attention task using hierarchical letter stimuli. We found that young and old participants differed in their movement accuracy as well as in their ability to suppress distractors in the hierarchical letter task. Specifically, older adults showed increased movement error in the presence of distractors (but not when distractors were absent). Interestingly, the errors exhibited by the older participants reflected greater avoidance of the distractor in reaching for the target (i.e., older adults tended to reach away from the distractor in an exaggerated manner compared to young participants). Moreover, we also found a correlation (controlling for age) between a measure of attention suppression in the hierarchical letter task and the size of the reaching error. We suggest that motor control in the presence of distractors relies on suppression of the visual representation of the distractors (cf. Chapman et al., 2012) which may decline with age.

43.3012 Aging Affects Temporal Processing of Motion and Depth from Motion Parallax

Jessica Holmin[1](jessica.holmin@ndsu.edu), Mark Nawrot[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

An important aspect of successfully interpreting the environment is the ability to quickly process dynamic visual cues, such as motion parallax (MP). However, older adults often require longer temporal processing intervals to recover various types of visual information. Here we investigated how age affects neural processing times for the perception of depth from MP. To assess processing delays, we measured threshold stimulus durations (stimulus-onset-asynchrony, or SOA) necessary for younger and older observers to make motion and depth judgments without interference from a high-contrast pattern mask. In four different conditions, observers made judgments about motion direction or depth phase. In two separate motion conditions observers reported the direction of relative image motion or the direction of motion of a translating stimulus window. In two separate MP conditions, observers reported the depth phase of a two different translating stimuli (4 deg/sec) that both required a pursuit eye movement. Threshold SOAs in each task were found using an adaptive procedure. Pursuit accuracy (gain) for a translating target (4 deg/sec) was also measured. Overall, observers required briefer SOAs to recover motion information, compared to SOAs in the MP tasks. In all four tasks, older observers had higher SOAs than younger observers. In the motion conditions, older observers' SOAs were 2-3 times higher than younger adults'. In the MP conditions, older observers' SOAs were 60-65% higher than younger adults'. This age-related difference in SOAs in MP conditions is smaller than might be expected, given the much larger difference in processing times in the motion conditions. There was no difference in pursuit gains between younger and older observers. These results indicate that the processing time required to recover depth from MP is not as affected by age as is the time required to recover motion information.

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43.3013 Foveal centre surround contrast suppression reveals differential effect of ageing on binocular and interocular suppression

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Healthy ageing alters foveal surround suppression of apparent contrast (FSSAC). The neural basis of FSSAC is considered to reflect several V1 neuronal receptive field properties. Primate V1 neurons have distinct transient/sustained (Bair et al, 2003) and early/late (Webb et al, 2005) surround suppression mechanisms. Here, we tested whether similar properties are manifest for FSSAC and if so, are they altered by ageing? We measured the apparent contrast of a centre circular vertically oriented sinusoid (20% contrast, 4c/deg) alone or in the presence of an annular sinusoidal surround (40% contrast, 4c/deg) present foveally. Nineteen younger (aged 19-32) and 19 older (aged 61-78) adults were tested under two viewing conditions (binocular: centre and surround in both eyes; interocular: centre and surround in different eyes), two surround configurations (No/Parallel surround) and two stimulus durations (40ms/200ms). Suppression strength was calculated as Apparent ContrastNo Surround – Apparent ContrastParallel Surround. In both groups, using binocular viewing, stimulus durations of 40ms produced stronger suppression than 200ms, however, both stimulus durations produced similar amounts of suppression interocularly (stimulus duration X viewing condition: $F(1,36)=7.19, P=0.01$). This suggests that binocular FSSAC has increased surround adaptation for longer duration stimuli, but not the interocular FSSAC. For both stimulus durations, older adults showed increased binocular suppression relative to the younger group, however, interocular suppression was similar (age X viewing condition: $F(1,36)=7.94, P< 0.01$, age X stimulus duration: $F(1,36)=0.04, P=0.84$). Our data suggests that ageing alters surround suppression at a processing stage before binocular combination of visual signals, either prior to or including the input layers of V1.

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43.3014 Turn up the noise: Increased visual noise in the M-pathway in older adults

David Chan[1](davidyt.chan@mail.utoronto.ca), Liza igochine[1], Lynn Hasher[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

Visual information in humans is processed by two separate visual pathways. One is the magnocellular visual pathway (M-pathway), which carries high temporal frequency information but low spatial frequency information. The other is the parvocellular visual pathway (P-pathway), which carries low temporal information but high spatial information. Currently, very little is known about how these pathways may change with age. In order

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to investigate this issue, we presented older and younger adults with low and high spatial frequency gabors under two critical conditions. The first, a pulsed pedestal condition, is known to inhibit the M-pathway, while the second, a steady pedestal condition, leaves both the M and the P-pathways intact. With younger adults, as expected, we found that they are faster at processing low spatial frequency (LSF) information under the steady pedestal condition, in which the M-pathway is unaffected. This replicates previous findings with younger adults. Also as expected, this bias is removed under the pulsed pedestal condition, where no preferential processing is shown between low and high spatial frequency information. These findings replicate earlier work (e.g., (e.g., Abrams & Weidler, 2014; Goodhew et al., 2014). Regarding older adults, we demonstrate the same pattern in the steady pedestal condition; faster processing of LSF information. Interestingly, an even greater inhibition towards LSF information is produced under the pulsed pedestal condition, such that now speeded processing occurs towards HSF information. We argue that this difference in older adults provides evidence that the M-pathway, although very much intact, may contain more internal noise, manifesting itself in a greater inhibition of low spatial frequency processing when the M-pathway is repressed.

Acknowledgement: NSERC

43.3015 Saccadic adaptation is preserved across adult lifespan

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Whereas cognitive changes across adult lifespan have been intensively studied, sensorimotor changes are not well understood. Saccadic eye movements are extremely well suited to investigate visuomotor control and several studies have explored age-related changes in saccadic control, but plasticity processes have been neglected so far. We were particularly interested in whether the ability of the oculomotor system to compensate for systematic foveal endpoint errors deteriorates with age. We investigated backward saccadic adaptation in 20 young subjects (M=29.3 years, range 21-39 years) and 21 senior subjects (M=68.7 years, range 61-75). Subjects had to make horizontal saccades to targets presented at 12 deg eccentricity. After a baseline we applied a double step paradigm in which the target was displaced to 8 deg eccentricity during the saccade. In the baseline session, we observed, consistent with previous findings, an increase of saccadic latencies with age. Neither accuracy nor precision of saccadic control was affected by age. For the double step trials we examined magnitude and rate of gain adaptation. Young and senior subjects were equivalently able to adapt to sensorimotor discrepancies. We found no difference in plasticity parameters during adaptation. In the post-adaptation session, though, age groups differed significantly in persistent amplitude change relative to the baseline session. Whereas younger subjects still showed an amplitude reduction of 3.8%, amplitude in senior subjects was just reduced by 1.6%. Our results provide evidence of robust oculomotor plasticity across a broad age range. However, more pronounced persistence of amplitude change after adaptation in younger subjects points to age-related differences in consolidation of motor learning.

43.3016 Attention training in normal aging: Role of implicit learning

Yuhong Jiang[1,2](jiang166@umn.edu), Wilma Koustaal[1,2], Emily Twedell[1]; [1]Department of Psychology, University of Minnesota, [2]Center for Cognitive Sciences, University of Minnesota

Aging is associated with impairments in functions that rely heavily on the prefrontal cortex, such as selective attention. To deal with potential information overload, older adults must rely on preserved functions. But which functions are preserved, and how can they help compensate for reduced capacity in selective attention? This study investigates one candidate mechanism – implicit learning. Previous research suggests that implicit learning is preserved in only simple, not complex, tasks in older adults. Here we tested implicitly learned attention in healthy older adults (60-80 years) and young adults (18-30 years). In Study 1 participants searched for a letter T among letter Ls. We introduced a learning component by placing the target T in one visual quadrant more frequently than in any of the other quadrants. Consistent with the idea that top-down attention declines with age, older adults showed longer response time (RT) and steeper RT-set size slope, relative to young adults. However, both groups demonstrated faster RT in the high-probability quadrant than the low-probability quadrants, even when they were unaware of the target's location probability. This learned attentional preference was durable, persisting over 200 trials of extinction training in both groups. Study 2 examined the spatial reference frame in which the frequently attended locations were coded. Participants were trained to prioritize one quadrant of the monitor placed flat on a stand. After training they changed their viewpoint by 90º. Older adults, like younger adults, showed a strong attentional bias toward locations in the same visual field as the previously trained high-probability locations. This finding suggests that learning induced a search habit that was viewer-centered. Study 3 showed that an explicit instruction to prioritize environment-centered locations can partially override the viewer-centered search habit in older adults. We conclude that implicitly learned spatial attention is preserved in healthy aging.

Acknowledgement: Engdahl Family Research Fund NIH

43.3017 Changes in Visual Attention with Normal Aging

Eriko Self[1](eself@fullerton.edu), Sam Handelman[1], Alexander Le[1], Moire Sigler[1]; [1]Department of Psychology, California State University, Fullerton

Performance of various cognitive tasks is known to decline with normal aging. The goal of this study was to assess possible changes in selective attention due to aging in a visual search task. Each trial began with a fixation cross presented for 900 ms, followed by a cue word (red, green, blue, or yellow) for 800 ms, and a second fixation cross (750 ms). Then the search screen was presented consisting of 8 hollow circles aligned in a circular configuration, each containing a grey line in either vertical or horizontal orientation. The target circle was displayed in the color indicated by the cue word, whereas the distractor circle was displayed in one of the remaining three colors. The other six circles were grey. The task was to report the orientation of the line inside the target circle by pressing one of two buttons. The cue word was displayed either in the target color (matching), the distractor color (mismatching), or grey (neutral). The line orientation inside the target was either the same as that inside the distractor (congruent) or different (incongruent). The search screen was displayed until the participant responded. The participants were younger adults (ages 18-27, n = 37) and older adults (ages 65-74, n = 31). A linear mixed model was used to predict RT from age group, target-distractor congruency, and cue color type. As expected, older adults showed longer RT than younger adults. There was no significant difference between congruent and incongruent conditions, indicating both groups showed successful endogenous attentional control. There was a significant effect of cue type on RT, suggesting that attention was influenced by the font color just like Stroop task. Interestingly, older adults showed no significant difference between the neutral and mismatching cue conditions. This potentially shows weaker interference in older adults.

Perceptual Organization: Shapes and objects

Monday, May 16, 8:30 am - 12:30 pm

Poster Session, Banyan Breezeway

43.3018 Slant-induced shape distortion in the Distorted Curve Illusion

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We present the Distorted Curve Illusion, a new illusion of slant-induced shape distortion. Slanted inducers (parallelograms) distort the perceived profile of adjacent curved shapes (semi-ellipses) by making the minimum-point of the curve appear laterally shifted. The curve appears compressed on one side and extended on the other. We measured the illusion using matching (Experiment 1) and the method of adjustment (Experiment 2). Based on previous illusions of elongation (Coren & Girgus, 1972; Schloss, Fortenbaugh, & Palmer, 2014), we predicted that the illusion would be reduced when the similarity between the inducer and target decreased. In Experiment 1, participants viewed configurations containing a parallelogram inducer (black or white), which shared its bottom edge with the flat side of a black semi-ellipse target. Below, there was a row of nine comparison curves. The center curve was a perfect semi-ellipse (0 pixel shift). The minimum-point of the four curves rightward/leftward of center had +/-4, +/-8, +/-12, and +/-16 pixel shifts, respectively. Participants indicated which comparison curve appeared to match the target curve. We tested three target curvature conditions (0, +/-4 pixel shifts) and 5 inducer slants (0, +/-15°, +/-30°). When the target and inducer were the same color and slants were moderate (+/-15°), the perceived minimum of the target curve shifted to assimilate with inducer slant. The illusion diminished for large slants (+/-30°). Surprisingly, the opposite was true when the target and inducer were different colors (interaction $p < .001$). The perceived minimum-point shifted in the opposite direction of the inducer slant, with increasing magnitude as the inducer slant increased. Experiment 2 produced similar results when participants matched an adjustable curve to the perceived curvature of the target. The pattern of results can be potentially explained by assimilation of shapes within the same reference frame and contrast between shapes in different reference frames.

Acknowledgement: Center for Vision Research, Brown University

43.3019 Temporal Properties of Abstract Shape Representation

Nicholas Baker[1](nbaker9@ucla.edu), Philip Kellman[1]; [1]University of California, Los Angeles

Background: Shape is an abstract notion, as evidenced when we can see a closed contour figure from dots around a virtual contour, when a cloud appears to resemble a fish, or when we can match shape across transformations of scale and orientation. Abstract shape is not likely represented in initial visual feature registration; it must be computed. We investigated the time course of the emergence of abstract shape representations. Design: Novel shapes defined by black and white dots along the contour were generated and displayed on a gray background for between 30 and 400 msec, followed by a dot mask for 100 msec, which blocked further encoding of the first shape. A second shape was then shown, and subjects performed a forced choice same-different task. "Same" shapes were defined as having the same dot-defined shape outline, whether the same in location, orientation and size, or across a 2D transformation of translation, rotation or scaling. "Different" shapes were constructed by deformation in the outline of the original shape. Results: Subjects were not significantly above chance with 30 msec of presentation time. Performance improved monotonically up to 110 msec of presentation time, after which performance was stable. All transformation types showed similar patterns. Intermediate levels of performance occurred for presentations greater than 30 and less than 110 msec. Control experiments showed that early visual feature registration, such as dot locations, are available during the first 30 msec after stimulus onset. Conclusions: These results suggest that abstract shape representations require about 110 msec to form. This result is not explainable by the time course of early visual feature registration, but appears to involve more time-consuming processes that extract shape.

43.3020 Percepts from noise patterns: The role of fractal dimension in object pareidolia

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The human visual system allows us to form percepts, mental states associated with having the experience of seeing a coherent form, even when there is no object present. Here we asked subjects to form percepts from silhouette images of fractal terrains that we generated with the random midpoint displacement method. We converted the terrains into binary images by applying a color scheme of black below and white above the median height, which resulted in silhouette fractals that range in fractal dimension from $1 < D < 2$. The fractal dimension quantifies the ratio of coarse to fine structure in the fractal terrain and therefore acts as a measure of its visual complexity. Participants were told that they would see a black and white image for one minute and were asked to press a button as they named aloud objects they saw. We recorded participants' response times and the number of objects named per image. At the end of the naming period for each image, participants were asked to draw an outline of each percept. Fifty-four participants each saw 16 images, four images from four levels of fractal dimension (1.1, 1.3, 1.5, and 1.9). Statistical analyses revealed significant linear and quadratic trends for both the response time and rate of naming data. Participants formed percepts fastest around dimension 1.3, and named the most objects at this level of complexity as well. At other levels of dimension, responses were slower and fewer objects were named. Processes that allow us to deal with occlusion and camouflage in natural environments may allow us to induce pareidolic states when viewing noise. Fractal image statistics may enhance the likelihood of such an occurrence in patterns with dimension near 1.3, as fractals with dimension nearer 2 exhibit greater fragmentation, whereas lower dimensions exhibit larger coherent regions.

43.3021 Does form-cue invariance hold at the individual contour or the integrated object level of representation?

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Previous studies show that segmentation of a center from its surround by either a physical or illusory contour attenuates the perceived chromatic fluctuation within the center (Elliott & Shevell, 2013). This is consistent with form-cue invariance, which holds that the neural representation of the edge of an object is equivalent whether due to a physical luminance edge or an illusory (Kanizsa) contour. It is not clear, however, whether form-cue invariance extends to integrated subparts of an object or applies to only a whole object composed entirely from physical or illusory contours. A combination of illusory and physical contours was used to create the percept of a square centered in the central 2 deg area of a larger 6 deg surround. Specifically, 0, 1, 2, 3 or 4 sides of the square had "pac-men" located to invoke the percept of an illusory-contour side. The remaining sides of the square were formed by a physical luminance edge. The central test, its surround, and a separate matching disk were modulated in luminance, all in-phase at 2 Hz. Observers adjusted the Michelson contrast of the matching disk to equal the perceived modulation depth within the central test. Results indicated that regardless of how the square was defined, perceived modulation within it was attenuated. This result is consistent with form-cue invariance for the individual integrated subparts of an object.

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43.3022 Finding a face on Mars: a study on the priors for illusory objects

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This study explores the ability of human observers to find illusory objects in various kinds of noise. The propensity to see such illusory objects in nature (often called "pareidolia") has been widely reported but has been the subject of only a handful of studies. However, recent work with deep learning networks (e.g., Deep Dreams) has shown that such networks will hallucinate such objects if one relaxes their recognition criteria. This study investigates the sensitivity and priors that humans have when searching for illusory objects in various types of noise. Method: In the first study, 24 observers were presented with 512x512 pixel noise images in which the amplitude spectrum slope varied between 1.0 and -4.0 (f1 to f-4). Observers were asked to search for a particular object (e.g. a face or a horse or a car) although such objects were never imbedded in the images. We measured the time required to find such targets in the noise (with a 30 second limit) and measured their confidence (a measure of the quality of the image they found). In the second study, we allowed observers to report any targets they found without cuing for any particular object. For all cued objects, we found that the probability of finding a target was highest and the time required to find a target was lowest when the spectra of the noise was between f-1 and f-2 (near the spectra of natural scenes). The confidence was also highest at these slopes. Faces were the fastest objects found and in general, animate objects were found faster than inanimate objects. We interpret these results in terms of the priors that observers have when finding objects in the world.

43.3023 Spatial memory demands modulate shape representations

Sami Yousif[1](sryousi@emory.edu), Vladislav Ayzenberg[1], Stella Lourenco[1]; [1]Emory University

For decades, scientists have struggled with the problem of object recognition. Human vision allows for the rapid recognition of objects even when presented from different viewpoints, requiring a representation that is both detailed and computationally efficient. The medial axis is one possibility. Recently, when subjects were tasked with spontaneously tapping once within a shape, the aggregated taps revealed evidence of a medial axis for various shapes (Firestone & Scholl, 2014). Nevertheless, it is unclear whether the medial axis representation is recruited for other processes such as object memory. Here we examined whether bias to the medial axis is modulated by spatial memory demands. Borrowing from a classic paradigm (Huttenlocher, Hedges, & Duncan, 1991), we asked participants to memorize the locations of either 1 or 20 dots within a rectangle and, once the dots had disappeared, to "place" those dots in their original locations. When only one dot was present, participants showed no bias in relation to the medial axis ($p > .30$) but were, instead, biased towards the "prototypes" of the rectangle's quadrants ($p < .001$). In contrast, with 20 dots, participants were significantly biased towards the medial axis over and above any bias towards other models (e.g., principal axis [$p < .01$], or center of rectangle [$p < .001$]). These findings suggest that humans have access to multiple shape representations that are task dependent. When the task requires recalling multiple locations, participants rely on a representation that captures the medial axis. However, when the task requires recalling a single location, subjects appear to maximize the precision of their estimates by segmenting space into smaller units (i.e., quadrants). We suggest that whereas a medial axis representation may be ideal for capturing a spatial "gist", other representations (i.e., segmentation with prototypes) are better suited to precise localization within a shape.

43.3024 On the mystery of fractals in Arts – why are Pollock's drip paintings valued so highly? Johannes Zanker[1](j.zanker@rhul.ac.uk), Jade Jackson[2], Jasmina Stevanov[3]; [1]Department of Psychology, Royal Holloway, University of London, England, [2]Department of Cognitive Science, Macquarie University, Australia, [3]Psychologisches Institut, Johannes Gutenberg-Universität Mainz, Germany

Measurement of the physical complexity of Jackson Pollock's paintings (fractal dimension 'D'), suggested a systematic increase of drip painting complexity during the development of his iconic style (Taylor, 2002). These findings exemplify novel approaches in experimental aesthetics to close the gap between physical descriptions of arts and objective perceptual measures of properties discussed as tokens of perceived beauty (Berlyne 1971), such as complexity, regularity, symmetry, or liking. We have developed a quantitative method to assess individual preference for complexity and liking in a set of patterns or paintings, by rank-ordering multiple combinations of smaller stimulus sub-sets (ECVP 2015, Perception 44-S1). We cropped 4 square regions at different locations from 10 Pollock paintings with known D (1943-1952), to generate 16 quasi-random samples of 5 crops that participants ranked by stepwise elimination of the preferred crop in the given set (assigned to them a 1-5 score). The rank for a given painting, calculated as average score of its crops (8 presentations each), is regarded as a measure of its perceived complexity/liking relative to the other paintings in the set. We observed some variation for individual observers, but some clear preference profiles for the 10 paintings: whereas perceived complexity appears to correlate well with liking, there is no systematic relationship between perceived complexity and fractal dimension, D. Could our observers' "blindness" to physical complexity (D) be a result of colour which strongly affects the aesthetic experience of the paintings but is neglected in the conventional estimations of D? In a second experiment, we used the same method with the same stimulus set converted into (normalised) grey-scale images – leading to very similar results. There is no substantial relationship between the fractal dimension of Pollock paintings and their perceived complexity and liking. Observers show greater preference to what they perceive as more complex!

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43.3025 Perceived Beauty and Polygon Shape Regularity Jay Friedenberg[1](jay.friedenberg@manhattan.edu), Veena Cherian[1], Jillian Enyart[1]; [1]Department of Psychology, Manhattan College

The Gestalt psychologists used the phrase Pragnanz to mean "good figure" yet did not quantify the term. One type of goodness is geometric regularity. A polygon is regular if it's sides and angles are equal. When asked to rate typicality or to draw triangles and quadrilaterals, participants are biased toward regularity (Feldman, 2000). In the current study we investigate whether this shape property affects aesthetic judgment. We manipulated regularity along a continuum by fixing the length of one side of a triangle and allowing the lengths of the remaining two sides to vary. The procedure produced equilateral, scalene, right and isosceles triangles equated for size. Twenty-two undergraduate participants observed versions of these triangles presented in multiple blocks at different random orientations. They rated the perceived beauty of the shapes using a seven point (1-7) rating scale. The standard deviation of the sides $F(7, 21) = 191$, $p < 0.01$ and angles $F(7, 21) = 218$, $p < 0.01$ significantly predicted judgments with a better statistical fit for angles. Symmetry also predicted judgments with ratings higher for shapes with more reflectional symmetry axes. The results demonstrate an aesthetic preference for shapes with increased geometric regularity. In preliminary data from a second experiment using quadrilaterals, we varied regularity again by altering the ratio of two side lengths. For all quadrilateral types (square, rectangle, parallelogram, rhombus, kite and trapezoid) there was a preference for regular and symmetric shapes $F(3, 60) = 139$, $p < 0.01$. Feldman, J. (2000). Bias toward regular form in mental shape spaces. Journal of Experimental Psychology: Human Perception and Performance, 26, 152-165.

43.3026 Evaluating Temporal Interactions Between Pairs of Shapes Michael Slugocki[1](slugocm@mcmaster.ca), Catherine Duong[1], Allison Sekuler[1], Patrick Bennett[1]; [1]Department of Psychology, Neuroscience and Behaviour, McMaster University, Hamilton, Ontario, Canada

Previous work evaluating temporal interactions between shapes defined by radial frequency (RF) contours has demonstrated that thresholds for detecting curvature along a target shape increase in the presence of a forward or backward mask, though backward masks presented at stimulus onset asynchronies (SOAs) between 80-100ms result in the most dramatic elevation in thresholds (Habak et al., 2006). If a pair of masks is used, where the first mask is presented concurrently with the target, and the second mask is presented at the peak backward SOA, the two shapes exert the same magnitude of masking as is observed when a single mask appears at the same SOA onset as the first mask shown in sequence (Habak et al., 2006). The current study aimed to extend these previous finding by examining how the effect of masking changes when the second mask is presented at both positive and negative SOAs, as forward masking using pairs of masks has yet to be explored. We measured detection thresholds for an RF5 contour in the presence of a surrounding RF5 mask presented at the same time as the target, along with a second RF5 mask presented at one of five different SOAs (-100ms, -50ms, 0ms, +50ms, +100ms). Consistent with previous findings, the strength of the pair of masks remains approximately the same between the zero and +100ms SOA condition. However, two out of the three observers show a significant increase in the effect of masking when the second mask is presented at negative SOAs, where the effect of masking is strongest at a -100ms SOA. Overall, these results suggest that there exist important differences in the dynamic interactions that occur between isolated versus pairs of shapes across time.

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43.3027 Perceiving order: Visual working memory encoding as a basis for judgment Justin Reed[1](justinreed.camosun@gmail.com), Ru Qi Yu[1], Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

The environment contains many different forms of regularities, such as repetitions (e.g., AAAA) and alternations (e.g., ABAB). While these simple forms of regularities have been studied heavily in the context of randomness perception, another type has received relatively less attention, which involves order (e.g., 12345). How does the visual system represent order? Here we hypothesize that the perceived degree of order is determined by the encoding difficulty in visual working memory. Participants viewed 7-digit sequences with varying degrees of order. A fully ordered sequence was 1234567, and a fully shuffled sequence could be 6231745. Each sequence was presented for 1s, and participants were immediately asked to recall the sequence. After the recall phase, participants rated each sequence on how shuffled it looked. We found that recall accuracy linearly improves with higher degrees of order (Experiment 1). Importantly, recall accuracy correlates with perceived order which is the subjective ratings of how shuffled the sequence looked. We replicated the experiment with sequences of lines with increasing lengths, and found that recall accuracy of line sequences can also be predicted by perceived order (Experiment 2). Using a decreasing order (e.g., 7654321), we found that recall accuracy again improves linearly with higher degrees of order, and can be predicted by perceived order, for both digit sequences (Experiment 3) and line sequences (Experiment 4). Moreover, The length of the sequence (i.e., 7, 8, or 9 digits) did not seem to influence the results (Experiment 5). The current findings provide support for our hypothesis that the perceived degree of order is determined by the encoding difficulty in the visual working memory. This suggests that visual working memory performance can serve as a basis for the judgment of order.

Acknowledgement: NSERC Discovery Grant

43.3028 Semantic Priming Facilitates Figure Assignment For Both Intact Familiar Objects And Their Parts (Despite Predictive Coding Error) Kimberley Orsten-Hooge[1](kim.orsten@gmail.com), Rachel Skocypec[1], Mary Peterson[1,2]; [1]Department of Psychology, University of Arizona, [2]Cognitive Science Program, University of Arizona

Cacciamani, et al. (2014) demonstrated that representations of intact familiar objects can be accessed by their parts, even when those parts are arranged in novel configurations. This follows fMRI research by Peterson et al (2012) who found that even when arranged in novel configurations the familiarity of a collection of parts is represented at high levels in the visual system associated with semantic representations. Here, we investigate whether activating semantic representations for a familiar object facilitates the perception of critical regions depicting that object and/or its parts as figure in a figure-ground task. We used bipartite displays wherein two equal-area regions share a central border. In each display one "critical" region depicted either an intact familiar object or a novel object created by rearranging inverted parts of a familiar object. To prime semantics, we preceded the displays with brief exposures of words that were either semantically related or unrelated to the familiar objects depicted in the displays. Results indicate that subjects were more likely to see critical regions as figure when they depicted intact familiar objects ($p = .006$), and when they were primed with a related word ($p = .009$). However, there were no differences in the prim-

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ing effect for intact versus part-rearranged objects despite our attempt to disrupt part familiarity by inversion. This suggests that semantic priming enhanced the familiarity of inverted parts. The data also suggest that an attempt may have been made to fit models of objects named by the primes to the displays, which would necessarily result in predictive coding errors because the primes never named the familiar objects present in the displays. Semantic priming effects were observed against this background of predictive coding error, which lowered overall reports of critical regions as figures.

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43.3029 **Empty space is less crowded: stereo-defined 3D letters exhibit less crowding when they are concave than when they are convex.** Anthony Cate[1,2](acate@vt.edu), Michael Hartman[1]; [1]Psychology Department, Virginia Tech, [2]Center for Human-Computer Interaction, Virginia Tech

INTRODUCTION: The perception of figural shape from concave and convex 3D images has been found to rely on different local features even when their 2D projections are identical and when their global shapes can be perceived to be equivalent. This study investigated whether this difference corresponds to the same kind of feature detection processes believed to underlie visual crowding. METHODS: 20 healthy participants with normal or corrected vision (and screened for stereoacuity) identified capital letters (6˚) displayed briefly (150 ms) at 11˚ eccentricity in random dot stereograms on a CRT monitor synchronized with LCD shutter glasses. Regions interior to the planar contours of letters were rendered with either crossed or uncrossed disparities to produce convex or concave stimuli. Disparities increased smoothly and nonlinearly to a maximum of 6′ at points defined by a letter's morphological skeleton. The main independent variable of figural depth structure (convex/concave) was crossed with the additional variables of target identity (13 possible letters), flanker presence (none or vertically aligned) and visual hemifield (left or right of fixation). Flanker letters could have three different spacings (roughly 1, 2 or 3 letter height units). Visual crowding was measured as identification rate for flanker displays minus single letter displays, separately for convex and concave conditions. RESULTS: Single letters were more difficult to identify when concave versus convex (79% versus 62% correct). However, concave letters also showed significantly less crowding (performance 41% versus 52% below baseline; above chance in both cases). Analysis of confusion showed qualitative differences in the patterns of errors for concave and convex letters. CONCLUSION: We interpret these results to mean that concave and convex letter recognition rely on qualitatively different feature detection processes. This difference may correspond to the coarse/fine feature detection bandwidth criterion for crowding proposed by Pelli et al. (2004, JoV).

Perceptual Organization: Mechanisms and models

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Banyan Breezeway

43.3030 **An Underadditivity of the Cellular Mechanisms Responsible for the Orientation Contrast Effects of the Rod-and-Frame Illusion** David Adams[1](adams4@uoregon.edu), Scott Reed[1], Paul Dassonville[1]; [1]Department of Psychology & Institute of Neuroscience, University of Oregon

If a vertical line is surrounded by a tilted frame, it is typically perceived as being tilted in the opposite direction. This rod-and-frame illusion is thought to be driven by two distinct mechanisms. Large frames cause a distortion of the egocentric reference frame, with perceived vertical biased in the direction of the frame's tilt (i.e., a visuovestibular effect). Small frames are thought to drive the illusion through local contrast effects within early visual processing. Wenderoth and Beh (1977) found that the visuovestibular effect could be induced by a stimulus consisting of only two lines, indicating that an intact frame was not necessary to achieve the illusion. Furthermore, Li and Matin (2005) demonstrated that the Gestalt of an intact frame provided no additional impact to the illusion, as the visuovestibuar effect of an intact frame was less than the sum of its parts. It is unclear whether the same is true for the local contrast effects caused by small frames. Participants performed a perceptual task in which they reported the orientation of a target line (12′ in length) presented in the context of either an intact frame (32′ on a side, tilted ± 15°) or partial frame (that is, flankers consisting of either the top/bottom of the frame in collinear locations with respect to the target line, or the left/right sides in lateral locations). Significant contrast effects occurred for all stimulus conditions, with the top/bottom flankers causing an effect substantially larger than that of the left/right flankers. Indeed, the effect of the top/bottom flankers even surpassed that of the intact frame, indicating that the overall effect of the frame was a weighted average of the two flanker conditions. These findings suggest an underadditivity of the cellular mechanisms responsible for the contextual effects of lateral and collinear flankers.

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43.3031 **Stereoscopic information disrupts the closure grouping effect in discrimination task but not in detection task** Junjun Zhang[1](jjzhang@uestc.edu.cn); [1]School of Life Science, University of Electronic Science and Technology of China

A closed contour was considered as a perceptual bridge from 1D contour to 2D shape (Elder, 2015). Those closed contours can be easier detected (Zhang et al., 2009; Gerhardstein et al., 2012) and discriminated (Elder and Zucker, 1993, 1994) than non-closed (open) contours. The continuity of such contours could be disrupted by depth information (Nakayama, 1996). However, it's still unknown whether this discontinuity of contours in 3D will then disrupt the closure grouping effects. In another word, it's unknown whether a retinal closed but 3D open contour is still easier to be detected and discriminated. Two experiments were reported here to test the effect of stereoscopic information on closure grouping. In the first experiment, random-dots stereograms were used to test the detection on closed and open figures. Each figure was presented either in only one depth plane, or with upper part in one depth plane and lower part in another depth plane. Results showed the detection on closed figures was easier, even when the figures were presented with segmentations in two depth planes. In the second experiment, visual search task was used to test the ability in discriminating among closed or open figures. Each figure was also presented in only one depth plane or with segmentations in two depth planes. Results showed searching among closed figures were slowed down when each figure was presented with segmentations in two depth planes. Such effect was not observed in searching among open figures. These two experiments showed that the stereoscopic information disrupted closure grouping in discrimination task but not in detection task. It indicated that the stereoscopic interpretation involves in the perceptual organization not at the very beginning, but before the fully understanding of the 2D information.

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43.3032 **MIB as noisy excitable system** Mikhail Katkov[1](mikhail.katkov@gmail.com), Noya Meital-Kfir[1], Alexander Cooperman[1], Dov Sagi[1]; [1]Department of Neurobiology, Brain Research, Weizmann Institute of Science Rehovot, 76100, Israel

Perceptual disappearance of a salient target induced by a moving texture mask (MIB: Motion Induced Blindness) is a striking effect poorly understood. Here we ask whether the mechanisms underlying MIB represent an excitable system. Excitable systems exhibit fast switches from one state to another (e.g., visible/invisible) induced by an above threshold perturbation, and a stimulus independent dynamics followed by a refractory period. In the experiments disappearance was induced by masks consisting of slowly rotating radial bars placed at different eccentricity relative to the target leading to periodic perturbation of the visual field around the target (a bright parafoveal spot or Gaussian blob, surrounded by a protection zone where bars were not shown). The bars passing around the target location induced an abrupt target disappearance within a range of rotation speed (up to 95%, depending on condition, ~0% without bars), pointing to locality. As expected from excitable systems, disappearance time was not affected by additional bars crossing the target during invisibility. Also, adding a second set of rotating bars, with a displaced center, increased invisibility time only slightly, but significantly. After the target reappeared, it stayed for at least 0.5-2 sec (refractory period). Overall, slowly moving bars are very good inducers of perceptual disappearance when targets are visible, while hardly affecting an invisible target. Invisibility periods (0.5-2sec on average) show little dependence on mask configuration. Therefore, the mechanisms governing MIB represent an example of an excitable system where transition to the invisible state is induced by the mask, with the following dynamics determined mostly by internal network properties. The implementation of such systems requires two components with substantially different time scales, such as adaptation and inhibition. Additionally, variability in invisibility periods and less than perfect efficiency in invisibility induction by the mask, point to the presence of noise in the dynamics.

43.3033 **Interactions between figure-ground organization and contrast perception: a neurocomputational model tested by White's illusion** Naoki Kogo[1](naoki.kogo@gmail.com), Jan Knopp[1], Hartwin Ghekiere[1], Vicky Froyen[2]; [1]University of Leuven, [2]State University of New York

The lightness and the depth perceptions are two fundamental properties of vision. Importantly, it is possible that the perception of images are established by dynamic interactions of the processes underlying the lightness and depth perception in the visual system. However, how these two computational processes interact is unknown. A neurocomputational model called DISC model (differentiation integration for surface construction) was developed to compute "border-ownership" signals that indicate the figural side at a border (Kogo et al., 2010, Psych. Rev.). The model has been improved further by implementing the detection of long-range consistency of surface properties and showed robust responses. In this new model, the interaction between the depth and the lightness computations can be made in the form of "differentiated signals", i.e. the border-ownership (difference of depth) and the contrast (difference of achromatic color), and the depth and lightness values can be computed by the 2D integration of these signals. In the well-known lightness illusion, "White's illusion", the perceived lightness of the target surfaces differs from what is expected by contrast enhancement suggested by the simultaneous contrast illusion. Involvement of the depth order perception in the lightness computation to explain this illusion has been suggested (Ripamonti & Gerbino, 2001, Perception). Hence, the illusion is the ideal case to test the approach described above. We tested the model not only with the classic White's illusion but also with the "inverted White's illusion" (Spehar et al., 2002, Perception). Because of the complexity of the figure and the gradual reversal of the figure-ground organization in the perception of the image, the image was split into two vertical halves. With this configuration, the computed lightness was shifted to the directions matching the psychophysical data. We report the details of the algorithm and the responses of the model.

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43.3034 **Local Contrast Gain Control Determines Global Form Percept in Glass Pattern** Yih-Shiuan Lin[1](yihshiuan.lin@gmail.com), Pao-Chou Cho[1], Chien-Chung Chen[1,2]; [1]Department of Psychology, National Taiwan University, [2]Neurobiology and Cognitive Science Center, National Taiwan University

A Glass pattern consists of randomly distributed dot pairs, or dipoles, whose orientation is determined by a geometric transform, which defines the global percept that would be perceived by an observer. The perception of Glass patterns involves a local process to associate dot pairs into dipoles and a global process to group the dipoles into a global structure. To further clarify the relationship between the local and global processes, we used patterns consisted of tripoles, or groups of three dots, as stimuli. In each tripole, three dots formed the vertex of an equilateral triangle with the anchoring dot pointing toward the center of the display. Grouping the anchoring dot with one of the context dot (D1) would lead to the percept of a clockwise spiral while the other dot (D2), a counterclockwise spiral. We manipulated the contrasts of the two context dots and measured the percentage of a participant judging the patterns as clockwise (CW) or counter-clockwise (CCW) at various combinations of contrast of the dots. When the contrast of D1 increased, the probability of perceiving CW first increased then decreased. Such inverted-V shape function cannot be accounted for by the energy model for form perception (Prazdny, 1984), which would predict a monotonic increasing function. The peak D1 contrast increased as D2 contrast, inconsistent with the similarity theory, which predicts that the peak would always occur when the D1 and the anchor have the same contrast. Our result was well fit by a contrast normalization model, in which the response to local dipoles is the sum of dot contrast raised by a power and divided by an inhibition signals driven by all dots in the tripole. The local responses are then pooled to determine global percept. Our model potentially reconciles the long disputed contradiction between the two previous models.

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43.3035 **Temporal dynamics of global/local processing** Ling Liu[1,2](ling.liu@pku.edu.cn), Huan Luo[1,2]; [1]Department of Psychology, Peking University, [2]IDG/McGovern Institute for Brain Research, Peking University

It has been suggested that processing of global and local properties are associated with neuronal oscillations at different rhythms. Recently, by employing a time-resolved behavioral measurement, several visual attentional studies have revealed neurophysiologically relevant rhythms directly in behavioral performances, suggesting that the underlying neuronal dynamics might be manifested directly at the behavioral level. Here we applied this time-resolved behavioral approach to access the temporal dynamics of global/local processing. The stimuli are a big arrow (global) composed of small arrows (local). The global and local properties are either congruent or incongruent. After cued by a text of 'Global' or 'Local', subjects reported the global or local properties of the target as fast as possible and their reaction times were recorded. The cue-to-target SOA varied from 110 to 600ms in steps of 10ms. First, we replicated typical global precedence effects (global faster than local) in slow trends of the time-resolved behavioral time courses. Second, with the slow trends removed, the global processing demonstrated a rhythmic fluctuation at alpha band (~10 Hz) and in phase between the congruent and incongruent conditions, suggesting that the global property is sampled in an alpha-band rhythm, not influenced by local properties. Relatively in contrast, the local processing showed an 'out-of-phase' relationship between the congruent and incongruent conditions, implicating that local processing is largely driven and modulated by the global property. Third, the local processing demonstrated a trend towards beta band (~30 Hz) in congruent condition. However, under incongruent condition, the local processing shifted towards the alpha-band rhythm, suggesting the strong modulations of local processing by global properties. Our results provide behavioral evidence supporting the central role of neuronal oscillations in global/local processing. Our study also speaks for a dynamic framework within which global and local properties are processed and dynamically interacted with each other.

43.3036 **Two Centroid Mechanisms in Vision** Jordan Rashid[1](jrashid@uci.edu), Charles Chubb[2]; [1]Cognitive Sciences, University of California, Irvine, [2]Cognitive Sciences, University of California, Irvine

Previous studies have investigated the natural strategies humans use to locate the centroid of a shape but have not provided performance feedback; thus little is known about the range of strategies humans can use to estimate locational summary statistics. This study used three tasks that differed in trial-by-trial feedback to probe the strategies subjects can use to extract the central tendencies of spatially distributed visual input. The stimuli in all three tasks were clouds of dots whose positions were drawn from a circular, bivariate normal distribution, presented for 150 ms, and followed by a post-stimulus mask. In each task the subject strove to mouse-click a different target location. In the "Mass" task, the target was the centroid CM of dot locations. In the "Hull" task, the target was the centroid CH of the convex hull of the dot cloud (i.e., of the smallest convex polygon surrounding all of the dots in the cloud. In the "Boundary-dots" task, the target CB was the centroid of the locations of all stimulus dots that fell precisely on the convex hull (not shown in the stimulus). Performance in each task is modeled assuming responses are a weighted average of CR, CM, and CB, corrupted by Gaussian noise. In each of the Mass and Hull tasks, responses were determined primarily by the appropriate target location and performances were corrupted by low noise. Comparisons of the estimated model parameters fit to each subject suggest idiosyncratic strategies in the Boundary-dots task, but in all cases responses are corrupted by more noise than the other tasks. We conclude that subjects are able to quickly and accurately compute CM or CH, but cannot compute CB.

Acknowledgement: University of California, Irvine

43.3037 **The contrast-dependence of the intermingled numerosity illusion explained** Adam Reeves[1](reeves@neu.edu), Quan Lei[1,2]; [1]Dept. of Psychology, Northeastern University, Boston MA 02115, [2]Dept. of Psychology, University of Minnesota,Minneapolis, MN 55455

Last year we reported a new illusion in which there seem to be up to 36% fewer white disks than grey disks when N randomly-located white disks are intermingled with N grey disks on a dark grey field. Similarly, on a light grey field, there seem to be fewer black than dark grey disks. Grey disk numerosity is not affected by intermingling; the illusion is entirely due to the salient set, white or black. When the intermingled disks are segregated by shape, motion, or depth plane, or when the disks are presented side-by-side, the illusion disappears. We now report that blurring the intermingled disks almost eliminates the illusion, as does reducing the size of the grey ones. In our model, perceived numerosity is the 0.87th power of N.sqrt(CE)/C, the square-root of contrast energy normalized by peak-to-trough contrast (C). When disks are segregated, CE is the square of the disk-field luminance difference, contrast normalizes out, and perceived numerosity depends only on N. However, field luminance is averaged with grey disk luminance when computing the CE of intermingled white or black disks, reducing their perceived numerosity.

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43.3038 Adaptation to Symmetry Axis Yui Sakata[1](sakata@cvs.cs.tsukuba.ac.jp), Ko Sakai[1]; [1]Dept. Computer Science, University of Tsukuba

Symmetry has long been considered as an influential factor for grouping and figure-ground segregation as well as a candidate for representing shape as medial axis. A recent psychophysical study has reported the adaptation to symmetry in random dot patterns [Gheorghiu, Bell & Kingdom, VSS 2014]. We investigated whether symmetry axis is a basis for symmetry perception. Specifically, we examined whether symmetry axis is an adaptable feature in the visual system. To examine whether adaptation alters the perceptual tilt of symmetry axis, we generated a set of stimuli that consisted of mirror-symmetric arrangements of random dots. The stimuli were comprised of tens of random dots so that their symmetry axes were invisible. A pair of stimuli whose axes were tilted ±10o from the vertical was presented for adaptation. Another pair of stimuli with a distinct dot pattern/contrast was presented for test. Using a staircase procedure, we measured the apparent tilt of the symmetry axes (Tilt-After-Effect). The results showed significant TAE, with the magnitude similar to ordinary TAE observed with solid lines. Similar TAEs were observed for the adaptation with a sequence of the short presentation of distinct patterns/contrasts, indicating that the TAE was evoked by the symmetry axis but not by pattern/contrast. We also performed another set of experiment with natural contours as adapter, and observed significant TAE. These results indicate that symmetry axis is an adaptable feature in the visual system, suggesting that symmetry axis is a basis for symmetry perception. To understand the cortical mechanism underlying the adaptation, we examined the retinotopy of the TAE. Our results showed the significant TAE even when the adaptation and test stimuli were presented 90o apart across the median line, indicating the hemispherical transfer of the adaptation. These results indicate the representation of symmetry axis in a higher visual cortical area.

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43.3039 A Bayesian model for the interaction of accretion/deletion and occluding-contour geometry in determining relative depth Ö. Dağlar Tanrıkulu[1](odt7@rutgers.edu), Jacob Feldman[1], Manish Singh[1]; [1]Psychology Department, Rutgers, The State University of New Jersey

Accretion/deletion is traditionally believed to unambiguously specify depth order, by assigning ground status to the accreting/deleting side. However, accretion/deletion can also result from self-occlusion of a 3D object rotating in depth. Thus an accreting/deleting region can also be perceived as being in front (Froyen et al, 2013, JOV). This phenomenon has been a focus of study recently (Tanrikulu et al., 2013, 2014, 2015, VSS), where it was shown that the perception of 3D columns rotating in front can occur in regions that should be unambiguously in back according to traditional accounts of accretion/deletion. Specifically, 3D rotation was perceived in one set of regions despite the constant-speed motion of the textures (which is clearly inconsistent with 3D rotation). It was also found that increasing the degree of convexity of the boundary on one side makes the accreting/deleting region on that side more likely to be interpreted as a 3D object rotating in front. Current computational models cannot accommodate these findings. Here, we present a computational model of relative depth and motion interpretation that accounts for the rich interaction described above. It is a Bayesian model that estimates the relative probability of interpreting accreting/deleting textures either as a flat surface translating behind or a curved 3D object rotating in front. The model takes into account the speed profiles of the accreting/deleting textures and the geometry of the occluding contour in terms of its convexity (treated as a quantitative factor). The effect of accretion/deletion is incorporated into the model through qualitative constraints which are then combined with the quantitative information about contour convexity and the speed profile of the texture. In this way, the model can account for variety of phenomena described in the literature that cannot be explained by existing computational models of accretion/deletion and relative-depth judgments

43.3040 Highly correlated internal noise across three perceptual and cognitive modalities Greta Vilidaite[1](gv529@york.ac.uk), Miaomiao Yu[1], Daniel Baker[1]; [1]The University of York

Neural variability (noise) is an important limiting factor in neural processing widely observed in neurophysiological studies. Abnormal levels of neural noise have been implicated in some neurological disorders such as Autism. Noise in the early visual system can be measured using noise masking paradigms in which stimulus noise is used to inject external variability. However, previous research has not been able to compare this noise in other cognitive modalities. We used a 2AFC double-pass paradigm (Burgess & Colbourne, 1988, J Opt Soc Am A, 5: 617-627) in which stimulus intensity was jittered on a trial-by-trial basis for three discrimination tasks: a) grating contrast; b) facial expression intensity; and c) numerical summation (in which participants were asked which set of four numbers had the higher sum). The tasks were repeated twice with 200 trials/rep and consistency of responses between the passes was calculated. We tested 43 neurotypical observers and also obtained an estimate of autistic traits with the Autism Quotient (AQ). There were substantial significant positive correlations between consistency scores across all three modalities: faces and numbers (Spearman's $\rho=.63$, $p< .0001$), faces and contrast ($\rho=.71$, $p< .0001$) and numbers and contrast ($\rho=.56$, $p< .0001$). Furthermore, a Principal Components Analysis showed that all three consistency scores load onto a single factor, which explained 77% of the variance. Individual observers' factor loadings were also found to be significantly negatively correlated with AQ scores ($\rho=-.39$, $p=.009$, two-tailed), suggesting that those with more autistic traits had higher internal variability. Our results imply either a single source of late decision noise, common across all tasks, or a common factor of endogenous noise across the various brain regions involved in each task. Our finding of lower response consistency in people with higher levels of autistic traits supports current theories of increased internal noise in autism.

Acknowledgement: N/A

43.3041 Exploring the effects of decisional bias on perceptual process characteristics in the context of a visual illusion Michael Wenger[1](michael.j.wenger@ou.edu), Lisa De Stefano[1], James Townsend[2], Mohammad Abdolvahab[2], Yanjun Liu[2]; [1]Psychology, Cellular and Behavioral Neurobiology, The University of Oklahoma, [2]Psychological and Brain Sciences, Indiana University

There is now a substantial literature documenting the ability to use strong-inference theory-based experimental methodologies to determine the fundamental characteristics of human information processing. The meta-theory known as systems factorial technology (SFT, Townsend & Nozawa, 1995), applied by way of an experimental task known as the double-factorial paradigm (DFP), has allowed for insights in tasks ranging from simple detection to complex face processing. However, much less is known about the effects of factors such as shifts in decisional bias on the stability and interpretablity of results. We present an investigation in which we induced shifts in decisional bias within observers. Participants performed a DFP task, based on the Hering illusion; stimuli were composed of two sets of vertical lines positioned equidistant from center, from which projected radial lines. Participants gave a positive response if they judged either or both sets of vertical lines to be curved outward, otherwise giving a negative response. Participants learned and performed the task with neutral payoffs; half of the participants were then switched to a positive and half were switched to a negative bias condition. Participants shifted to a positive bias showed reliable decreases in mean reaction times (RTs), increases in false alarm (FA) rates, and negative shifts in measures of response bias. All of these participants showed evidence for parallel self-terminating processing before and after the shift. Participants who were shifted to a negative response bias showed reliable increases in mean RTs, decreases in hit and FA rates, and positive shifts in response bias. All of these participants showed evidence for parallel self-terminating processing before the shift; there was evidence for both parallel exhaustive and serial processing after. The results suggest the robustness of the SFT/DFP approach and motivate the need to further develop theoretical models that can incorporate both RT- and accuracy-based metrics.

Acknowledgement: National Science Foundation

43.3042 An Entropy Theory of Correlation Perception Ronald Rensink[1](rensink@psych.ubc.ca); [1]Departments of Computer Science and Psychology, University of British Columbia, Vancouver, Canada

The perception of correlation in scatterplots with gaussian distributions can be described by two simple laws: a linear one for discrimination and a logarithmic one for perceived correlation magnitude (Rensink & Baldridge, 2010). The underlying perceptual mechanisms, however, remain poorly understood. To determine what these might be, just noticeable differences (JNDs) and perceived magnitudes were measured for 20 observers, for each of four conditions. The first tested scatterplots of 100 points with a bivariate gaussian distribution of equal variance in both dimensions; values of Pearson correlation r ranged from 0.0 to 0.9. JND was proportional to $u = 1-br$, with bias b such that $0 < b < 1$; perceived magnitude was proportional to $\log(u)$. The two functions were related via the common bias b for both JND and perceived magnitude. Three other conditions were also examined: a scatterplot with 25 points, a horizontal compression of the scatterplot, and a scatterplot with a uniform distribution of dots. For all conditions, the same laws were found to hold. The generality and nature of these laws—together with the finding that the same laws exist when features other than spatial position are used to map information to visual structure (Rensink, VSS 2015)—suggests that the underlying perceptual structure is not a geometric one such as the shape of the scatterplot dot cloud, but a probability distribution inferred from the dots, with perceived correlation proportional to its information entropy. This entropy theory not only explains the shape of the curves for discrimination and perceived magnitude, but also why they are related via their common bias b. More generally, these results also show that the graphical representations commonly used to display information form an interesting class of stimuli, one that can help us uncover important new insights into the nature of our visual intelligence.

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43.3043 **What is Perceptual Curvature?** Hao Wu[1](whao@yorku.ca), James Elder[1]; [1]Centre for Vision Research, York University

The curvature of a smooth curve in the plane is defined mathematically as the rotation of the tangent vector over an infinitesimal interval of the curve, but what is perceptual curvature? It must be something different, as the eye cannot resolve infinitesimals. Here we seek to understand how humans perceive the local curvature of natural shapes. Five observers viewed a sequence of white outline animal shapes at two viewing distances (75cm and 150cm). Each shape was scaled to have standard deviation of 1.56deg at 75cm. A random point on each shape was highlighted and the observer judged the curvature at this point. To avoid obscuring the contour, the judgement was made by placing a red dot at the perceived centre of curvature. We considered three models of perceptual curvature, each a function of an interval of the contour centred at the point of interest, based on the turning angle formed by the point of interest and the bounding points of the interval, and the sine and tangent of this angle. We first determined the subset of trials on which the signs of objective and perceptual curvature agreed, and then analyzed the correlation between the magnitudes of objective and perceptual curvature for this subset, as a function of the neighbourhood size. We found the turning angle model to be most predictive of perceptual curvature, with an optimal contour neighbourhood of 29arcmin at a viewing distance of 75cm. We expected the optimal neighbourhood at 150cm viewing distance to be either constant in a retinal frame (29arcmin) or in an object frame (14.5arcmin). What we found was intermediate (20arcmin), suggesting influence by both physiological and contextual factors.

Acknowledgement: NSERC CREATE Program in Vision Science & Applications

43.3044 **Capacity limit of ensemble perception** Anna Luo[1](annaxluo@gmail.com), Jiaying Zhao[2,3]; [1]Graduate Program in Neuroscience, University of British Columbia, [2]Department of Psychology, University of British Columbia, [3]Institute for Resources, Environment and Sustainability, University of British Columbia

The visual system is remarkably efficient at extracting statistical ensembles from objects in the environment, such as the mean size or orientation. Yet at any given time, multiple groups of objects can be randomly distributed over space. Thus, the challenge for the visual system is to summarize over multiple intermixed sets at once. What is the limit of the ability to perceive multiple ensembles? In a series of experiments, participants viewed an array of 1 to 8 spatially intermixed sets of circles for 1000ms in each trial. Each set contained four circles in the same colors but with different sizes. A probed set was randomly chosen from the array, and was either pre-cued or post-cued. Participants estimated the mean size of the probed set. Fitting a uniform-normal mixture model to the error distribution for each number of set, we found a four-set limit of ensemble perception: observers could reliably estimate the mean size of circles from maximally four sets (Experiment 1). Importantly, their performance was unlikely to be driven by a subsampling strategy (Experiment 2). By extending exposure durations to 1500ms and 2000ms, we found that the estimation of mean size might be constrained by internal capacity constraints even when the constraint from processing speed was eliminated (Experiment 3). In addition, ensemble perception may be limited by the storage capacity of visual working memory (Experiment 4). Finally, the capacity for ensemble perception does not seem to be influenced by the imprecise representations of individual circles in the set (Experiment 5). Overall, our findings suggest that ensemble perception can operate over multiple intermixed sets, but with a four-set capacity limit. This result converges with previously observed limits in visual working memory, attention, and enumeration. The convergence implies that different forms of visual processes may share a common capacity constraint.

Acknowledgement: NSERC Discovery Grant

43.3045 **We Need Closure: Inequality in Perceptual Grouping for Visual Working Memory** Sofia Neira[1](sofianeira@knights.ucf.edu), Joanna Lewis[1], Mark Neider[1]; [1]Department of Psychology, College of Sciences, University of Central Florida

Early research suggested a visual working memory (VWM) capacity limit of three to four objects (Luck & Vogel, 1997), but recent studies have indicated that the informational bandwidth of an object, which can vary with factors like complexity and amenability to perceptual grouping, can interact with this capacity (Brady, Konkle & Alvarez, 2011). For example, many individual features can be grouped into objects for an added benefit in VWM capacity (Xu, 2002). Along these lines, the Gestalt principles of proximity and connectedness have been shown to benefit VWM, although not necessarily in an equivalent manner (Xu 2006; Woodman, Vecera & Luck, 2003). The less explored principle of closure, akin to connectedness and proximity, promotes the perception of a coherent object without physical connections. In the current experiment, we evaluated whether closure produces similar or greater VWM capacity advantages compared to proximity by having participants engage in a change detection task. Four L-shaped features were grouped in tilted clusters to either form an object (object condition) or not (no-object condition), with a set size of either four (16 L features) or six clusters (24 L features). Following a brief mask (1000 ms), the orientation of one cluster was changed (tilted 20 or -20 degrees) on half of the trials. Participants were more accurate to report the change when features induced a sense of closure (58.89% set size 4, 55.09% set size 6) compared to when they did not (54.07% set size 4, 51.20% set size 6), suggesting that closure affords better VWM benefits than proximity. As evidenced through this subtle manipulation to feature groupings, our data suggests that perceptual grouping by closure is valid for forming objects representations, and, in at least some cases, it perhaps provides a greater indicator of "objectness" than other factors, such as feature proximity

43.3046 **No effect of unitization (connectedness) on the adaptation of perceived number** Emilie Shepherd[1](eshephe1@swarthmore.edu), Frank Durgin[1]; [1]Department of Psychology, Swarthmore College

There is some evidence, for small collections, that perceived number is affected by grouping or unitization of sub-elements. Do these grouping effects extend to large collections and do they affect adaptation to those collections? Here we consider whether using large collections of grouped units rather than separate element alters the adapting power of a collection. Our grouped units were composed by joining four lines ("legs") by means of a circular "body"; collections of these were compared to collections of un-connected lines. If unitization affects adapting power, than adaptation should be less for connected units. But if unitization fails for large collections, then 400 unconnected lines would be equivalent in adaptive power to 100 units composed of 4 lines and a central body. We tested this in two ways. First (N=28), we compared the strength of adaptation from 100 grouped units (adapted on one side of fixation) with the strength of adaptation from 400 unconnected lines (similarly adapted) when assessed with much lower numerosities in the adapted region (e.g, 12, 25, or 50 lines). For all of these numerosities, the average adapting power of 100 grouped units (M = 34% reduction following adaptation) was no different from the adapting power of 400 legs without bodies (M = 35% reduction following adaptation). We next (N=18) asked how adaptation to 100 connected units would affect the perceived numerosity of a field of 200 legs presented in the same location. Once again the effects of adaptation to 100 connected units did not differ from the effect of adapting to 400 unconnected legs in the same location. Adaptation to either of these stimuli reduced the perceived (matched) numerosity for 200 legs by about 25%. These data show that unitization by connectedness in large collections does not seem to modulate the adaptative power of those collections.

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Color and Light: Lightness and brightness

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4001 **Presence of a veiling luminance revealed by higher order variables involving luminance, saturation, and contrast.** Alan Gilchrist[1](alan@psychology.rutgers.edu), Cristhian Altamirano[1]; [1]Psychology Department, Rutgers University Newark

Observers exhibit lightness constancy both when the illumination level on a scene is increased and when a homogeneous layer of light (a veiling luminance) is added to the scene, even though these transformations of the retinal image are very different and no lightness theory can explain both. When a Mondrian pattern is seen through a veiling luminance without visible borders, patches on the Mondrian appear much lighter gray and the veil is not perceived; zero constancy. But when the same veil covers a 3D scene of equivalent luminance range, lightness constancy is almost 100% and the veil is perceived. What information is used to reveal the veil and estimate its strength? We report nine experiments using a new apparatus that allows a light source to be placed either at the virtual location of the eye (thus eliminating both cast and attached shadows) or 25 degrees away from the eye. We found: (1) Lightness constancy is significantly better (blacks look blacker; veil perceived) when shadows are present. Adding a veil creates a positive correlation between the contrast at a shadow boundary and the luminance of the surface it falls on. Without the veil there is no such correlation; all shadow boundaries have equal contrast. (2) Adding colored patches to the Mondrian had no effect while adding colored objects to the 3D scene produced better constancy. In this case, adding a veil creates a positive correlation between the saturation gradient across a curved colored object and the luminance gradient across it. (3) A weakly colored veil (24% purity) produced better constancy than a neutral veil. In this case the veil creates a negative correlation between the saturation gradient across a curved achromatic object and the luminance gradient across it. Constancy was significantly lower when the curved objects were replaced by rectangular objects.

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43.4002 Measuring perceptual scales of perceived surface lightness: a comparison between MLDS and matching

Christiane Wiebel[1](christiane.wiebel@tu-berlin.de), Guillermo Aguilar[1], Marianne Maertens[1]; [1]Modelling of Cognitive Processes Group, Technische Universitaet Berlin

Perceived lightness is often measured by asking observers to specify a test field that best matches their percept of a target. Typically one is interested in measuring lightness constancy, i.e. to what extent observers choose the same matches across viewing contexts that lead to variations in the luminance signal of the target. Such a procedure is called asymmetric matching which points to the potential problem that perceived lightness must be compared between different viewing contexts. The procedure of maximum-likelihood difference scaling (MLDS), on the other hand, allows the estimation of perceptual scales from judgments of stimulus differences along one stimulus dimension. That is, perceptual lightness scales can be obtained for lightness judgments performed within different viewing contexts and should theoretically map to the same internal scale, given lightness constancy. Here, we wanted to test this by measuring perceived lightness as a function of different viewing contexts in a matching and an MLDS procedure. Stimuli were rendered images of variegated checkerboards. Perceived target lightness was assessed for ten different reflectance values and five different viewing contexts (plain view and four transparencies). In the MLDS procedure we used a triad comparison, i.e. observers indicated which of two pairs of checks, presented in the same viewing context, appeared more different in lightness. In the matching procedure, observers adjusted an external test field to match the lightness of the target check. We found a high correspondence between the two procedures. In the MLDS procedure similar perceptual scales were estimated for each viewing context indicating a mapping to the same internal dimension. Simulations of MLDS scales on either luminance- or reflectance-based judgments showed that the observed scales were more consistent with reflectance-based judgments. As observers reported unanimously that the triad comparison was the more intuitive task, MLDS might provide an interesting alternative to standard matching procedures.

Acknowledgement: This work was co-funded by the German Research Foundation (GRK 1589/1 ``Sensory Computation in Neural Systems", and DFG MA5127/1-1)

43.4003 Perceived illumination anchored by the highest luminance.

Cristhian Altamirano[1](cristhia@scarletmail.rutgers.edu), Alessandro Soranzo[2], Alan Gilchrist[1]; [1]Psychology Department, Rutgers University Newark, [2]Psychology Deptartment, Sheffield Hallam University

Theorists like Helmholtz (1866/1924) and Katz (1935), proposed that perceived illumination within a field is based on the average luminance within the field. Recent experiments done through a vision tunnel, show evidence that perceived illumination is associated with the highest luminance, not average. Four experiments were run. Experiment 1: Observers looked through an aperture into a vision tunnel. Two windows were located at the far end of the vision tunnel. Each window opened into a chamber with variable illumination. The observer's task was to adjust the illumination level in one window (by turning a knob), to equal that in the other window. The left window revealed a black and white checkerboard (0.23 cycles per degree) while the right window revealed a white and light gray checkerboard. Illumination in both windows was higher than in the tunnel. Experiment 2: Identical, except that the checkerboard had a higher spatial frequency (0.81 cycles per degree). Experiment 3: Illumination in the windows was lower than that in the tunnel. A low frequency checkerboard was used. In all three experiments, observer matches were based closely on the highest luminance, not average. Experiment 4: Using a data projector, two round spotlights were cast on a 128-patch Mondrian mounted on a lab wall. One spotlight fell on a region with a full range of patches from black to white, while the other spotlight fell on a region with a truncated range of patches, only from black to mid-gray. Observers were instructed to adjust the illumination of one spotlight to match the other, using arrow keys on the keyboard. The spotlights were matched for highest luminance, not average. In all these cases the highest luminance in the field of illumination was perceived as white, laying the basis for a theoretical integration of lightness and perceived illumination.

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43.4004 Mismatch between perception and neural response in glare illusion

Yuta Suzuki[1](suzuki14@vpac.cs.tut.ac.jp), Takahiro Shinkai[1], Hiroshi Higashi[1], Tetsuto Minami[1], Shigeki Nakauchi[1]; [1]Toyohashi University of Technology

In the Glare illusion, brightness is boosted and even self-luminous impression is evoked, simply by surrounding luminance gradation. This study aims to investigate the underlying mechanisms by SSVEPs and psychophysics. We focused on the observation that luminance contrast of the flickering dots modulates SSVEP amplitude (Andersen et al., 2012). EEG experiment (Exp.1) was carried out to measure the SSVEPs evoked by the flickering dots displayed both on glare stimulus including luminance gradation (glare condition) and control patch surrounded by homogeneous luminance patches (control condition), with various luminance of the central region. Note that 2AFC experiment (Exp.2) confirmed the luminance enhancement in the glare condition. If the SSVEPs reflects the perceived contrast, larger amplitude is expected for the glare condition. However, obtained result was opposite: the SSVEPs was significantly lower compared with the control condition, especially for the high luminance contrasts stimuli. This suggests that the SSVEPs reflect neither physical nor perceived luminance contrast of the flickering dots. What factor can explain the reduction of the SSVEPs in the glare condition? We hypothesize that veiling reflection reduced the perceived contrast of the flickering dots and then SSVEPs decreased. To test the hypothesis, we measured the contrast threshold for detecting the flickering dots in both glare and control conditions (Exp.3). It turned out that the thresholds for both conditions showed no difference. We also measured the pupil responses to both conditions (Exp.4) and found that the pupil in the glare condition was significantly smaller than the control condition in high contrast. These results imply that the SSVEPs and the pupil responses to the glare stimuli reflects more cognitive factors, such as feeling of dazzling, rather than brightness perception. The cortical interactions between the early and the later visual areas may underlie for the modulation in the observed SSVEPs to the glare stimuli.

43.4005 Contextual effects and the contrast asynchrony: a new phenomenon shows a cancellation of contrast responses

Arthur Shapiro[1](arthur.shapiro@american.edu), Venice Cowardin[2], Angel Wen[3]; [1]Departments of Computer Science and Psychology, American University, [2]Department of Mathematics, American University, [3]Science Magnet Program, Montgomery Blair High School

The visual system has separable visual encoding for luminance and for contrast modulation (Shapiro, 2008); the two dimensions can be represented with a luminance contrast vs. luminance plane. Here we use a contrast asynchrony paradigm to explore contextual effects on luminance contrast modulation: two identical rectangular bars (0.5x1.0 deg) have luminance levels that modulate at 2 Hz; when one bar is placed on a bright field and the other bar on a dark field, observers perceive the bars modulating in antiphase with each other and yet becoming light and dark at the same time. The antiphase perception corresponds to the change in contrast between the bars and their surrounds (a change along the contrast axis of the plane); the in-phase perception corresponds to the luminance modulation (a change along the luminance axis of the plane). We examine spatial interaction by adding bright rectangular (0.5x1.0 deg) flankers on both sides of the dark-field bar and dark flankers on both sides of the bright-field bar. Remarkably, flankers produce an in-phase appearance when separated from the bars by between 1′ and 12′ of visual angle, and produce antiphase appearance when they directly adjoin the bars or are separated by more than 12′. To estimate the dimensions of the spatial interaction, we paramet-

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rically adjust the amplitude of modulation and the height of the flankers. We model the results in terms of spatial filters. We show that modulation produces two contrast phase responses: with distant flankers, the modulating rectangle against the dark background is in Phase A, and the rectangle against the white background is in Phase B; with adjoining flankers, the contrast phase reverses. The in-phase appearance for gaps between 1′ and 12′ seems to represent a perceptual cancellation of the two contrast responses.

43.4006 **Context-dependent Brightness Affects Perceived Contrast at Threshold and Suprathreshold Levels** Zahide Pamir[1,2](zahide-pamir@gmail.com), Hüseyin Boyacı[1,2,3]; [1]National Magnetic Resonance Research Center (UMRAM), Bilkent University, Ankara, Turkey, [2]Neuroscience Graduate Program, Bilkent University, Ankara, Turkey, [3]Department of Psychology, Bilkent University, Ankara, Turkey

Contrast is an important feature for performance on many visual tasks such as object identification, speed or motion detection (Kilpeläinen, Nurminen, & Donner, 2011). Perceived contrast of a grating depends on the luminance of its background. On the other hand, context often causes a large difference between luminance and its perceptual counterpart, brightness (e.g. simultaneous brightness contrast). Thus, characterizing different effects of luminance- and context-dependent brightness on contrast is critical. In this study we investigate how context-dependent brightness affects contrast judgements using a variant of Adelson's checkerboard illusion stimulus (Adelson, 1995). Two series of behavioral experiments were conducted. In the first series, we measured the perceived contrast of gratings using several different implementations of a method of adjustment paradigm. Participants reported the contrast of rectified gratings with incremental and decremental suprathreshold contrasts superimposed on equiluminant target regions, for various levels of frequency, background luminance and brightness, and photometric contrast. Results show that gratings superimposed on equiluminant but perceptually brighter target regions were perceived to have higher contrast than those superimposed on perceptually darker target regions (N=6). However, this pattern was only valid for incremental contrast, not for decremental contrast. In the second series of experiments, we measured the contrast detection thresholds using a 2-IFC procedure. We found that detection threshold is lower for the gratings superimposed on equiluminant but perceptually brighter target regions (N=6). Our results show that context-dependent brightness of the target region, not only its luminance, influences the perceived contrast of gratings both at threshold and suprathreshold levels. These findings unveil the significant effect of context-dependent brightness on contrast perception, thereby provide evidence that contrast perception does not depend only on the photometric quantities of the image formed on the retina, and that context-dependent factors also play a role.

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43.4007 **The Maximum Differentiation competition depends on the Viewing Conditions** Jesús Malo[1](jesus.malo@uv.es), David Kane[2], Marcelo Bertalmío[2]; [1]Image Processing Lab. Universitat de Valencia. Valencia. Spain, [2]Dept. Inf. Comm. Technologies. Universitat Pompeu Fabra. Barcelona. Spain

The optimization or falsification of vision science models can require time-consuming experimentation. This is especially true for models of artifact detection that require large databases of thresholds judgements or subjective image quality scores. Wang&Simoncelli (JoV, 2005, 2008) proposed a novel psychophysical method to avoid such experimental burden: the MAximum Differentiation (MAD) competition. This technique computes a pair of maximally different images according to each vision model under investigation, and the subject then selects the pair of images that they perceive to have greater difference. This paradigm is able to reduce the falsification of competing models to one experiment. As a result, MAD has been used to simplify the optimization of divisive-normalization contrast perception models (Malo&Simoncelli, SPIE 2015). The MAD paradigm is proposed in a context-independent manner and used on complex, unconstrained datasets. However, as a proof-of-concept, we demonstrate that the MAD paradigm can produce contradictory results in different surround conditions: these computational examples (based on luminance adaptation and the associated crispening effect, see supplementary material) show that the decision between models cannot be reduced to a single image comparison. On the contrary, it is mandatory to extend MAD, either by (1) doing a number of surround-dependent comparisons with the same images, which would reduce the conceptual advantage of MAD, or by (2) including the effects of the surround in the models considered in the MAD competition, which would give surround-dependent image pairs. REFERENCES Wang Z. & Simoncelli E.P. (2005) MAD competition: comparing quantitative models of perceptual discriminability. VSS Abstract. J. Vision, 5(8): 230-230. Wang Z. & Simoncelli E. P. (2008). MAximum Differentiation competition: A methodology for comparing computational models of perceptual quantities. J. Vision, 8(12): 8, 1–13 Malo J. & Simoncelli E. P. (2015). Geometrical and statistical properties of vision models obtained via MAximum Differentiation. Proc. SPIE, Human Vision Electr. Imag. Vol. 9394

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43.4008 **A quick display characterization method within local and limited input ranges of high color depth display systems for vision experiments** Hiroshi Ban[1,2](ban.hiroshi@gmail.com), Hiroyuki Yamashiro[3], Hiroki Yamamoto[4]; [1]Center for Information and Neural Networks, National Institute of Information and Communications Technology, Japan, [2]Graduate School of Frontier Biosciences, Osaka University, Japan, [3]Aino University, Japan, [4]Graduate School of Human and Environmental Studies, Kyoto University, Japan

Recent remarkable advances in display technology enable us to present visual stimuli with higher color depths. For instance, the current standard middle-range graphic boards and displays support 10-or-more-bit color depth for each of RGB channels. With those high color depth display systems, the standard gamma correction procedure to linearize the relationship between video inputs and luminance outputs may not be efficient in the following two reasons. First, the input/output relationship of the high color depth systems can be calibrated more accurately within a limited local color space since we can collect sufficient number of luminance/color samples around the target range, while the standard gamma correction procedure requires sparse measurements in a whole range of colors to describe the relationship with an exponential model. Second, a color transformation matrix obtained from the maximum RGB inputs to produce the required chromaticity may not be ideal in characterizing high color depth displays due to the nonlinearity of the systems. Therefore, we propose a novel display characterization procedure for high color depth displays. In this procedure, all the calibrations and estimations can be achieved only in a local luminance/color space, ignoring the irrelevant input range. Our aim is especially focused on developing a fairly quick and efficient method for finding display inputs that produce specific pre-specified luminance and chromaticity outputs. Specifically, our method consists of two estimation steps. First, the linearity between video inputs and luminance outputs is attained by measuring luminance outputs in a limited input space and by generating color lookup tables for that local space (Local Gamma-Correction). Second, the required RGB video input values are assessed by a local color transformation matrix estimated by least-squares estimations (Local Color Estimation). The whole procedures are integrated into GUI-based display characterization software, Mcalibrator2, written in MATLAB. The software is publicly available (https://github.com/hiroshiban/Mcalibrator2).

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43.4009 **Color Name Distances Scaled by Thurstone's Ranking Order Psychophysical Method** Marcelo Costa[1,2](costamf@usp.br), Carlo Gaddi[2]; [1]Departamento de Psicologia Experimental, Isntituto de Psicologia, Universidade de São Paulo, SP, Brasil, [2]Núcleo de Neurociências e Comportamento, Universidade de São Paulo, SP, Brasil

The psychological continuum of color names or categories is usually studied using categorization methods that have restricted information or statistical multidimensional scaling based on mathematical assumptions hardly controlled. The aim of our study is to scale color name distances using simplest experimental procedure which enables large-scale applications and for different population groups in an interval scale. Eighty two participants (mean age= 22,3 yrs; SD= 1,7) with normal or corrected to normal visual acuity and normal color vision were evaluated. The task consisted in write a column list of colors, one in each line, as fast as possible in a sheet of paper during the experimental period of 20 seconds. Intending to control replicating same-class colors names with one term were accepted. The data were analyzed based on the rank order scaling method proposed by Thurstone, in which the derived proportion of subjective separations was used to calculate subjective distances. The procedure consisted in calculate the frequency with which color A was placed in rank 1 by the N subjects comparing with the frequencies in which the other colors was placed in rank 1. The same comparison was performed by all other rank positions. Summing for the total number of ranks we could measure the probability that B was perceived in a rank order higher than A. Following, we calculated the Z-score to find the distances between probabilities. Our results shown that the color rank position were red>green(0,23)>blue(0,28)>yellow(0,31)>bla

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ck(0,32)>white(0,50)>purple(0,62)>orange(0,68)>brown(0,72)>pink(0,86). The numbers in the parenthesis are the subjective distances measured. We concluded that rank order is a simple task and produces quantitative interval class data that could be performed for a large group of population allowing studies and comparisons between them using the same method.

Acknowledgement: FAPESP(2013/04049-4),CNPq Edital Universal

Binocular Vision: Stereopsis

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4010 Binocular Integration for Behavior in Mice

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Despite the presence of disparity selective neurons in mouse primary visual cortex, there has been no evidence that mice integrate binocular cues to drive behavior. Previous work has demonstrated that rodents can estimate the size of a gap (Legg & Lambert, 1990; Kerr et al., 2013), but it is unclear from these studies whether the cues that are used are monocular or binocular. To determine whether binocular integration can drive behavior, we trained animals to distinguish between toward and away motion, presented dichoptically, for which the cues were only accessible by integrating information between the two eyes. Mice were trained to walk on a ball suspended in the air, while vertical gratings with spatial frequency of 0.02cpd was presented to each eye. Gratings moving in opposite directions for the two eyes generate motion through depth: "toward" stimuli are generated by presenting the left eye with a leftward grating and the right eye with a rightward grating; "away" stimuli are generated by presenting the left eye with a rightward grating and the right eye with a leftward grating. Mice were trained to walk on "away" stimuli and stop on "toward" stimuli and also walk on "right" stimuli, which was generated by presenting same rightward grating in both eyes. After training, mice are able to distinguish between toward, away, and right motion. Even though the animal was able to accomplish 100% correct on the task for some days, this was very rare. Most of the time the animal was able to get 70-90% correct which varied from day to day. This errors might be due to changes in eye positions or the animal losing focus during the train (such as grooming). This behavioral evidence demonstrates that mice can use binocular cues to drive their behavior.

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43.4011 The precision of stereopsis in the lower visual field.

Saeideh Ghahghaei[1](sghahghaei@gmail.com), Suzanne McKee[1], Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Macular degeneration (MD) results in vision loss in and around the fovea. When both eyes are affected, and there is binocular central field loss, individuals often adopt a peripheral preferred retinal locus (PRL) at the margin of the scotoma, with the scotoma above it and relatively intact visual field below this gaze position. We have shown previously that individuals with MD can benefit from stereopsis when roughly corresponding areas in the two eyes are used to view a target in depth (Verghese et al, 2014 ARVO). Depth perception can also be useful for navigation to avoid falling. For example, a curb with a drop of 15 cm subtends a disparity of 3 to 8 arcmin at a distance of 1 to 2 m, assuming an eye height of 150 cm and interpupillary distance of 6 cm. To determine whether intact peripheral retina has the disparity sensitivity to support such discrimination, we mapped stereoacuity thresholds across the lower visual field (horizontal, vertical and diagonal meridians) in three normally sighted participants. Consistent with previous studies (Fendick & Westheimer, 1983), our results show that stereoacuity declines as a function of eccentricity, roughly doubling every 3 degrees. Importantly, we find that stereoacuity in the lower visual field is 4 arcmin or better for eccentricities up to 14 degrees, which is near the limit of observed PRL distance from the old fovea in individuals with macular degeneration. This suggests that individuals with intact peripheral retina up to about 14 degrees eccentricity in the lower visual field have the potential to detect a curb drop off and avoid falling.

43.4012 Perceived depth from disparity depends on luminance contrast

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Binocular disparity is a precise depth cue and, in view of its derivation from binocular geometry, is generally considered to be independent of luminance contrast. Here, we provide evidence showing otherwise. The test stimuli were rectangular random dot stereograms (1.27 x 3.44 degree) of 100% density light and dark dots of 1 arc min extent that produced a percept of a surface with a sinusoidal modulation (0.29 or 0.87 cycle/deg) in depth. The observers' task was to adjust the length of a horizontal bar to match the perceived depth in the test stimuli as a function of the contrast of the random dots. The luminance contrast of random-dot array ranged from 5% to 80% of the mean luminance. At each contrast level, the matched depth increased with disparity up to about 10 arc min and then decreased with further increases in disparity. Both the amplitude and the peak position of the matched depth function increased as a sigmoid function of luminance contrast, only leveling out by about 40% contrast. These results show that perceived depth from disparity modulation depends strongly on the luminance contrast of the image. This result cannot be explained by a disparity energy model or any model that postulates the perceived depth as being determined by the disparity channel that gives the greatest response to stimuli, because those models would predict no effect of luminance contrast on perceived depth. Instead, the data can be explained by a multiple-stage model in which the perceived depth is determined by the weighted average of several nonlinear contrast gain control mechanisms, each with a different disparity selectivity.

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43.4013 Sensory eye dominance due to interocular imbalances of inhibition and integration

Chao Han[1], Teng-Leng Ooi[1], Zijiang He[2]; [1]College of Optometry, The Ohio State University, [2]Department of Psychological and Brain Sciences, University of Louisville

Sensory eye dominance (SED) refers to an unbalanced interocular contribution to binocular interaction. Generally, SED is larger in amblyopes than non-amblyopes, and perceptual learning protocols that reduce SED can improve stereopsis (Xu et al, 2010; Ooi et al, 2013). However, since binocular interaction includes both interocular integration and interocular inhibitory processes, it is important to investigate the interocular imbalance within each process (SED-integration and SED-inhibition). Experimentally, SED-integration can be measured by using dichoptic stimuli with similar image features, such as horizontal gratings with relative phase shifts (e.g., Ding & Sperling, 2006). In contrast, SED-inhibition can be measured with orthogonal gratings that induce binocular rivalry (e.g., Ooi & He 2001). An outstanding question is whether SED-integration and SED-inhibition are related as no study has yet measured both forms of SED on the same observers. To answer this, we measured SED-integration and SED-inhibition of observers with clinically normal vision (at least 20/20 visual acuity and 40" stereopsis). We also measured their stereo thresholds for detecting crossed and uncrossed disparity of random dot stereograms. And to explore whether SED has a possible contribution from the monocular pathways, we measured monocular contrast sensitivity. We found a high probability that the strong eye revealed in SED-integration was also the strong eye in SED-inhibition measurement even if the extents of SED were different. Observers with larger SED of either form tended to have higher stereo threshold for both crossed and uncrossed disparity. Observers with larger SED of either form could also have an interocular difference in contrast sensitivity, which nevertheless could not fully account for the SED. Taken together, our results suggest that while SED-integration and SED-inhibition reflect interocular imbalances, respectively in the excitatory and inhibitory processes, we cannot rule out the possibility that both forms of interocular imbalances are triggered by a common cause.

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43.4014 Effect of sensory eye dominance and unequal binocular contrast stimuli on stereopsis

Teng-Leng Ooi[1], Chao Han[1], Zijiang He[2]; [1]College of Optometry, The Ohio State University, [2]Department of Psychological and Brain Sciences, University of Louisville

Empirically, the extent of sensory eye dominance due to an imbalance of interocular inhibition (SED-inhibition) is gauged when the two eyes viewing a binocular rivalry stimulus achieve equal predominance. This occurs when the physical contrast levels of the rivalrous half-images are adjusted so that the weak eye receives a higher contrast level. It has been shown that observers with significant SED-inhibition have reduced stereopsis for binocular depth stimuli with equal contrast level (Ooi & He, 2001; Xu et al, 2011). However, it is not known how the stereo perception of observers with SED-inhibition is affected by binocular depth stimuli with unequal contrast levels in the two eyes. Here, we investigated this question by testing observers with clinically normal vision. SED-inhibition was measured using a pair of binocular rivalry stimulus with vertical and horizontal gratings. We then measured observers' stereo thresholds using random dots stereogram with different interocular log contrast ratio. For the range of log(interocular contrast ratio) tested (-0.4, -0.2, 0, +0.2 +0.4), we found an approximately V-shaped stereo threshold versus contrast ratio function with a minimum close to zero log(interocular contrast ratio). That is, stereo threshold was lowest when the physical contrast levels in the two eyes were similar. We also found asymmetric slopes in the two arms of the V-shaped function. Namely, the side of the arm where the strong eye received higher contrast level had a steeper slope indicating that stereopsis of observers with significant SED-inhibition can be compromised when more extreme contrast levels are uncompensated. A possible explanation is that the contribution of the interocular inhibitory mechanism to the stereoscopic process increases as the difference in physical contrast between the two eyes increases. Accordingly, having an unbalanced interocular inhibition impedes the stereoscopic process more so when the difference in interocular contrast is large.

Acknowledgement: NIH (R01 EY023374)

43.4015 **Disparity thresholds Dmin and Dmax both depend on interocular contrast difference**

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Previous studies have shown that the disparity threshold Dmin depends on the interocular contrast ratio. Dmin is lowest (best), when the interocular contrast ratio is 1. However, little is known about the dependence of Dmax on the interocular contrast ratio. In this study, we measured both Dmin and Dmax using random-Gabor-patch stereograms, in which, Gabor patches had random positions and phases, but with a fixed spatial frequency (3 cpd). The two eyes had two identical arrays of patches except that one eye's array could be shifted horizontally, and they could differ in contrast. We found that, for both Dmin and Dmax, performance was best when the two eyes had equal contrast, and declined when the contrast was reduced in either or both eyes. Ironically, reducing the contrast in one eye resulted in worse performance than reducing it in both eyes, consistent with previous studies on Dmin (Legge & Gu 1989; Hou et al 2011). We tested two models: (1) Energy model: the disparity energy is proportional to the product of the two eyes' contrast, and is then normalized (divided) by monocular contrast energy; (2) Double gain-control model (Ding & Sperling 2006): the contrasts in the two eyes are first mutually suppressed by each other (double layered), and then multiplied to compute disparity energy. Both models assume that the disparity energy is a function of disparity, the product of disparity power and exponential decay functions, which increases with stimulus disparity at small disparities but decreases at large disparities. Both models predict Dmin equally well (reduced-chi-square < 1.5); however, the gain-control model performs much better (reduced-chi-square < 2.5) than the energy model (reduced-chi-square > 5.5) for Dmax. Further work is needed to determine whether Dmin and Dmax share a similar network.

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43.4016 **Short-term monocular deprivation increases stereoacuity**

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Monocular deprivation early in life can impair vision permanently (Hubel and Wiesel, 1970), but deprivation during adulthood has been thought to be without effect. However, adults who were monocularly deprived for a few hours show a short-term gain increase in the formerly deprived eye relative to the undeprived eye (Lunghi et al., 2011; Zhou et al., 2013). This binocular imbalance should affect stereoacuity. We previously showed that stereoacuity improves after depriving each eye sequentially, presumably by increasing the gain in both eyes. Following that argument, we hypothesize that: (1) monocular deprivation should lower stereoacuity (as does an interocular mismatch in stimulus contrast), but (2) depriving both eyes simultaneously should improve performance because balance is preserved as gain increases. We measured stereoacuity with a two-line depth discrimination test immediately before and after deprivation. Deprivation consisted of covering one or both eyes with a translucent patch for 2.5h, in accordance with previous studies. The patched eye received only low frequency and low contrast inputs while the unpatched eye viewed the natural environment directly. Observers were stereo-normal adults. Binocular deprivation improved stereoacuity by 35%; but contrary to our predictions, monocular deprivation also improved stereoacuity by 27-55%. Alternating the eye being deprived in three cycles during the 2.5h period also improved stereoacuity by 40%. Stereoacuity gradually returned to pre-deprivation levels after deprivation. Improved performance was correlated with duration; prolonging monocular deprivation to 4.5h produced further improvement (67%), but 45min had no observable effect. Stereoacuity improved regardless of the type of deprivation (alternating, binocular or monocular). Therefore, our results suggest that monocular contrast gain control was not responsible for the effects induced by deprivation. Rather, sustained balanced binocular input appears to lower the gain of stereo mechanisms through an adaptation effect. Deprivation avoids the adapting binocular interactions, and allows transient recovery.

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43.4017 **Perceiving the stereo depth of simple stimuli isn't simple: The case of gratings.**

Bart Farell[1](bfarell@syr.edu), Cherlyn Ng[1]; [1]Institute for Sensory Research, Syracuse University

Horizontal disparities are directly linked to perceived stereo depth of two-dimensional stimuli but, surprisingly, the same does not hold for 1-D stimuli. 1-D stimuli, such as lines and gratings, have ambiguous disparity signals, an analog of the aperture problem in motion. One consequence is that the depth seen between two stimuli, one 1-D and the other 2-D, can vary with the orientation of the 1-D stimulus even if horizontal disparities remain unchanged. How relative disparities and orientations jointly affect the perceived depth between two 1-D stimuli is unknown. To determine the computation humans use, we had observers discriminate the depth order of a test grating presented in the context of a reference grating. Stimulus onsets were staggered over time. A reference grating was presented parafoveally, together with an identical fixation stimulus. After 1 second, a target grating was added to the display for 180 ms at the same eccentricity as the reference grating. Importantly, no other stimulus was available to mediate relative disparity calculations. We measured the disparity of the target grating required for the target and reference gratings to be seen at the same depth. We found that the size of this depth-matching disparity did not depend on horizontal disparity but instead was proportional to 1/cosine of the orientation difference between the two gratings. The sign of the depth-matching disparity varied with the reference grating's clockwise versus counter-clockwise orientation relative to vertical. Cyclotorsion cannot account for the results; the largest possible ocular rotation would be much too small. Instead, the relative depth seen between the gratings is what would be expected from a normalization process that resolved the stereo aperture problem by notionally rotating the context stimuli to vertical, thus defining a standard functional disparity axis for computing relative disparities.

Acknowledgement: Supported by NSF Grant BCS-1257096

43.4018 **Sensitivity to horizontal and vertical sine-wave corrugations defined by binocular disparity: factor analysis of individual differences reveals discrete processes with broad orientation and spatial frequency tuning**

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Sensitivity functions for horizontally- and vertically-oriented depth corrugations both peak in modulation spatial frequency at 0.2-0.4 cycles/degree, with higher sensitivity for horizontal than vertical corrugations (both defined by horizontal disparities). In order to elucidate the spatial frequency and orientation tuning of underlying processes, we analyzed two data sets using factor analytic techniques developed to estimate the number and tuning of spatial channels (Peterzell et al.,1993; 1995; 1996; 2000). The first set (Widdall et al., unpublished; 16 deg displays, n=30 individuals), was for 0.1, 0.2, 0.4, 0.8, and 1.4 (1.2 or 1.6) cycles/degree. A principal component analysis of disparity sensitivities (log arc sec) determined that two significant factors accounted for 70% of the variability. Following Varimax rotation to approximate "simple structure," one factor clearly loaded on to low spatial frequencies (0.4 c/deg and below), while the second was tuned to higher spatial frequencies (0.8 and 1.4 c/deg). Both factors had nearly identical tuning for horizontal and vertical patterns. In a second very small data set (Bradshaw & Rodgers, 1999; 20 degree displays, n=6 individuals), two or three factors accounted for 89% or 96% of the variability, with just one factor underlying the horizontal

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data, and at least two factors underlying the vertical data. The finding of separate factors for low and high spatial frequencies are consistent with previous studies (Witz & Hess, 2013; Serrano-Pedraza et al., 2013). The failure to find separate factors for horizontal and vertical corrugations in the larger data-set is surprising. Individuals' sensitivity to horizontal and vertical gratings were highly correlated at most spatial frequencies, even though the neuronal mechanisms are believed to be different, suggesting that sensitivity is limited mainly by the initial encoding of disparity.

43.4019 The effect of grouping by common fate on stereoscopic depth estimates

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When two vertical lines are perceived to form the boundaries of a common object, observers underestimate their separation in depth (Deas & Wilcox 2014, 2015). This disruption in perceived depth magnitude depends directly on the perceived grouping via closure of the resultant figure. It has been proposed that this phenomenon is due to constraints on disparity-smoothing operations by high-level object representations. In previous experiments, perceptual grouping was manipulated by varying the spatial layout of figural elements. However, if the reported disruption in perceived depth is a general outcome of perceptual grouping then it should also occur when elements are grouped via other spatio-temporal properties. Here we tested this prediction by varying the relative motion of figural elements to introduce the Gestalt cue 'common fate'. In all experiments, participants viewed the stimuli on a mirror stereoscope and used an on screen ruler to estimate the separation in depth between two vertical lines. In Experiment 1 we found that depth estimates were accurate over a range of suprathreshold disparities, for both static and moving stimuli. In a subsequent series of experiments, we progressively strengthened the grouping cues, but found no impact on depth magnitude estimates. This was true even when we used a more complex biological motion stimulus, and asked observers to judge the amount of depth between two joints. Despite the compelling motion-based figural grouping, there was no corresponding impact on suprathreshold depth percepts. Taken together, our results show that previously reported reductions in perceived depth from disparity are not generalizable to grouping via common motion. Instead, it appears that this phenomenon only occurs when the spatial layout suggests they belong to a common object.

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43.4020 Masking Effects in Cyclopean Surface Perception

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The perception of disparity-defined cyclopean form requires both the successful measurement of disparity and the linkage of multiple disparity measurements across the image. Performance limitations in cyclopean tasks may therefore depend on both difficulties arising at the disparity measurement stage and at later stages, where surface structure is determined. To assess the contribution of these factors in cyclopean tasks, participants were presented with disparity-defined random-dot sinusoidal corrugations in depth and asked to perform an orientation discrimination task. Corrugations were presented embedded in random-dot masks, which were structured as either random disparity distributions, or anti-phase disparity sinusoids. Multiple mask types were used in order to assess the contributions of both random and structured disparity signals in disrupting cyclopean performance. Thresholds were obtained for the number of masking dots required to reduce orientation discrimination performance to 75% correct levels. For random disparity distributions, mask-to-surface-dot ratios increased with increasing numbers of surface dots, ranging from 0.91 for 60-dot corrugations to 3.5 for 200-dot corrugations. For anti-phase masks with a 120-dot target corrugation, thresholds were around a mask-to-surface-dot ratio of 0.5, falling to chance performance by a ratio of 1. These results show that anti-phase mask structures are more effective at disrupting cyclopean performance than random disparity distributions. At a ratio of 1, where the numbers of mask and surface dots are equal, performance in the cyclopean orientation discrimination task improved, to above threshold performance, with increasing disparity amplitude of the corrugation, decreasing cyclopean frequency, or an increase in the total number of stimulus dots. Using a local cross-correlation model of disparity measurement, we show that psychophysical performance cannot be fully accounted for by a decrease in cross-correlation measures at target disparities, but must instead result from ambiguities arising in processes involved with the linkage of multiple disparity measurements.

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43.4021 The impact of disparity-based grouping on 3D slant perception

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The amount of depth perceived between two isolated features is dramatically reduced when those features are grouped to form boundaries of a surface (Deas & Wilcox, 2014). The strength of this disruption of depth perception is modulated by 2D grouping principles (e.g. closure and good continuation). Moreover, the reduction in depth perception also depends on the smoothness of the disparity gradient along the surface, which we called good disparity continuation (Deas & Wilcox, 2015). The aim of this series of experiments is to determine if the reduction in depth from disparity is a general property of smoothly varying surfaces. If so, it should not be restricted to these simple interpolated surfaces, slanted about a vertical axis. We replicated and extended previous experiments with simple line stimuli known to reduce perceived depth when connected to form surfaces. Four equally spaced lines were presented; the central pair was manipulated to create three conditions: isolated lines, a single closed object, and two closed objects. These configurations were presented vertically and horizontally in separate blocks of trials. The orientation manipulation had the important consequence of changing the direction of the disparity gradient in the two conditions. On all trials, observers estimated the amount of depth between the two central lines using a touch sensitive sensor strip. The results showed that when the closed object contained a horizontal disparity gradient, depth percepts were consistently reduced compared to isolated lines. However, this reduction was eliminated when the stimuli were orientated around the horizontal axis. The same pattern of results was obtained using a row of dots – which required no surface interpolation. We conclude that the reduction in suprathreshold depth percepts linked to good disparity continuation is specific to horizontal disparity gradients, and may partially account for well-known orientation anisotropies in 3D slant perception.

Acknowledgement: NSERC Discovery Grant and CREATE Grant

43.4022 Illusory occlusion can trump binocular disparity

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The combination of ordinal and metric depth cues poses problems for standard models of cue integration, because the two cue types do not have comparable units. When occlusion (ordinal) and binocular disparity (metric) cues conflict, one cue is sometimes ignored; other times, surfaces are perceived as transparent, broken, or bending to reconcile occlusion and disparity signals (Howard 2012). What visual features determine how occlusion and disparity combine remains unclear. It might be expected that sensory occlusion cues, such as T-junctions, are necessary for occlusion to influence stereoscopic depth perception. Here we show, instead, that completely illusory occlusion can trump binocular disparity. When a monocularly presented bar is filled in through the blind spot, it can be perceived as occluding a binocularly presented bar in the same visual region. Observers viewed a cross of textured bars of different colors through a stereoscope. One bar was presented monocularly, reaching through the blind spot; the other bar was presented binocularly. Observers judged the perceived depth of the binocular bar by comparing it to a single binocular bar with variable disparity in a 2IFC task. When the monocular bar was seen to occlude the binocular bar, depth estimates for the binocular bar were farther than in a baseline condition, where a binocular bar was presented in isolation. In contrast, when the binocular bar was perceived to be in front, it appeared as closer. In summary, a task-irrelevant illusory occluder overrides binocular disparity cues. Although the occluding surface is illusory, it is not subject to bending or other surface deformations. Instead, the perceived global depth ordering, which is not based on retinal cues, sets boundaries for the interpretation of metric stereoscopic depth estimates. Interestingly, filling-in seems to produce strong, opaque surface representations that provide functional contributions to other perceptual processes, such as depth estimation.

43.4023 Determination of the slope of the psychometric function for different stereoacuity tasks Ignacio Serrano-Pedraza[1,2](iserrano@psi.ucm.es), Kathleen Vancleef[2], Will Herbert[2], Maeve Woodhouse[2], Jenny Read[2]; [1]Faculty of Psychology, Complutense University of Madrid, 28223, Spain, [2]Institute of Neuroscience, Newcastle University, NE2 4HH, UK

Adaptive Bayesian procedures are widely used in psychophysics to estimate detection thresholds. Simulations have revealed the importance of the parameters selected for the model likelihood function in obtaining threshold estimates with small bias and standard error (Alcalá-Quintana & García-Perez, 2004). One recommendation is that the spread (sigma) of the model function has to be bigger than the real sigma of the psychometric function of the subject. The selection of a smaller sigma can introduce a bias in the threshold estimation and increase the standard errors. Here we wanted to estimate the value of sigma and find whether it changes with participant's age using three different stereoacuity tasks. Studies were performed using a stereo display with polarized glasses. In all studies we used an adaptive weighted one-up one-down staircase procedure with 80-120 trials and a logistic psychometric function was fitted to the probabilities of correct detection in order to estimate stereoacuity thresholds and sigma. In the first study, we used a spatial two-alternative forced-choice (2AFC) task for detecting a 3D square created by introducing horizontal disparities in dynamic random dots. In the second study we used the same stimuli but in a spatial 4AFC task. In the third study we used 4AFC too but using a computerized version of the clinical Randot stereoacuity test. In the first study we tested a population of 70 people (aged 4.6-61 years, mean 20 years). Results showed that sigma (mean=1.23,SD=0.88) was independent of age ($r=-0.01$, $p=0.92$) although it correlates with stereoacuity ($r=0.26$, $p=0.02$; sigma increases by 1.23 for every doubling in threshold). The second and third studies were performed with younger populations (4.74-21.8 years, mean 10.3 years) but results were similar; again sigma did not correlate with age. Therefore, to estimate stereoacuity thresholds with adaptive Bayesian-staircases we recommend using sigma = 1.8 independently of age.

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43.4024 Stereo-curvature Aftereffect at Multiple Processing Levels: an fMRI study Hiroaki Shigemasu[1](shigemasu.hiroaki@kochi-tech.ac.jp), Pengfei Yan[2]; [1]School of Information, Kochi University of Technology, [2]Department of Computer Science, College of Computer Science and Technology, Taiyuan University of Technology

It has not been clear what levels of cortical process are involved in stereo-curvature aftereffect ranging from retinal disparity to perceived shape process. In this study, we conducted an fMRI experiment to probe multi-level adaptation of stereo-curvature aftereffects across ROIs defined by retinotopic mapping and functional localizer. We used random dot stereograms which depicted horizontal hemicylinder for adaptation and test stimuli. In order to separately investigate the adaptation to distinct sources, we used two types of fixation point which (1) moved along Lissajous path in depth and (2) were static to manipulate adaptation to local retinal disparity, and used three types of adaptation stimuli which involved dynamic changes (1) in size, (2) in length of depth axis, and (3) no change to manipulate the levels of shape processing. Participants just fixated or tracked the fixation point in adaptation phase and observed test stimuli with static fixation in test phase. For the index of adaptation, we compared BOLD signal change from baseline during adaptation phase (6.6 s) and test phase (1 s). The results showed that adaptation effect without constant local disparity information was significantly smaller in V1, V2 and also middle dorsal area (KO/V3B). The adaptation to the shape related information was found in both dorsal and ventral areas but showed different properties among them. The size variant adaptation effect (i.e. the adaptation effect depended on the change of shape curvature) was found in POIPS region but the size invariance was found in VP and ventro-lateral areas (hV4, LO). Also, adaptation to the averaged disparity information seems to be processed in high dorsal area (V7) and IPS areas (VIPS/V7*, POIPS and DIPS), suggesting that these areas may involve a low-order calculation of disparity which may be used to encode depth metrically while ventral pathway encode categorical shape.

43.4025 Manual target tracking reveals a perceptual asymmetry between crossed and uncrossed disparities Jasmine Stone[1,2](jasminetstone@gmail.com), Kathryn Bonnen[2,3], Alexander Huk[2,3,4], Lawrence Cormack[2,3,4]; [1]Liberal Arts and Science Academy High School, Austin, Tx, [2]Center for Perceptual Systems, University of Texas at Austin, [3]Institute for Neuroscience, University of Texas at Austin, [4]Department of Psychology, University of Texas at Austin

Tracking a target with the hand is an alternative or enhancement to traditional push-button psychophysics. Here, observers were instructed to mirror the motion of a purely cyclopean disparity-defined target in a dynamic random element stereogram (DRES) using their index finger. During each 10 sec trial, the target moved in a 3-dimensional random walk, but it remained solely in either crossed or uncrossed disparity (i.e. either in front of or behind the larger surface). We did not inquire about the color of the DRES. The three-dimensional finger position was monitored in real-time (60Hz) using a Leap Motion controller. The data were analyzed by cross-correlating the target and finger velocities for each of the three cardinal motion directions. Surprisingly, tracking in horizontal and vertical directions (i.e. frontoparallel motion) was better than depth tracking ("better" = higher peak correlations and shorter latencies), even though disparity processing was required to see and therefore track the target at all. More surprisingly, tracking performance for crossed targets was markedly better than for uncrossed targets, despite disparity sign being the only difference. When static and centered, the crossed-disparity target was consistent with an object floating before a background, and somewhat consistent with the end of a pillar projecting from the background. The uncrossed disparity target was consistent with a surface viewed through an aperture, and somewhat consistent with the base of a tunnel. However, when the target began to move, only the first crossed disparity interpretation (an object floating) was plausible (pillars and tunnels have sides which should become more clearly visible when relative target position changes; apertures are generally in a fixed position on a surface). Thus, while the cause of the performance asymmetry is yet uncertain, we speculate that it was because moving crossed-disparity targets in DRES had a single plausible, figure-ground interpretation.

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43.4026 Vergence responses to fine and coarse disparities: Adult-like tuning functions at 5 years of age Kimberly Meier[1](k-meier@psych.ubc.ca), Deborah Giaschi[2], Laurie Wilcox[3], Eric Seemiller[4], T. Candy[4]; [1]Department of Psychology, University of British Columbia, [2]Department of Ophthalmology & Visual Sciences, University of British Columbia, [3]Department of Psychology, Centre for Vision Research, York University, [4]School of Optometry, Indiana University

Depth information can be extracted from small retinal disparities (fine stereopsis), or large disparities that give rise to diplopia (coarse stereopsis). Coarse stereopsis may mature early in life and be crucial for calibrating binocular pathways during development. This suggestion is consistent with previous work showing adult-like depth discrimination at 4 years of age for diplopic disparities, but not until 13 years for fused disparities (Giaschi et al., 2013). In the current study we used a new paradigm to assess disparity sensitivity in children using eye-tracking. Vergence eye movements were recorded in 10 adults and 10 five-year-olds with typical vision. Dichoptically-presented images were viewed through polarized lenses. During each of 260 trials, a cartoon character (2.2 deg wide) was presented in the plane of the screen for 1500 ms, stepped to a crossed or uncrossed disparity (0, 0.5, 1, 2, 4, 8, 16 deg) for 320 ms, and followed by a blank screen for 680 ms. Diplopia was then assessed by having participants report whether they perceived 1 or 2 characters at each disparity (in random sequence). Children and adults showed the same peak vergence amplitudes across the disparity range ($p > .05$). These tuning functions demonstrated increased amplitude as a function of disparity until ±2 deg, corresponding to the fine disparity range. Coarse disparities yielded vergence eye movements with reduced peak amplitudes, but in the expected direction in depth. This reduction of vergence amplitudes occurred over the range of disparities that appeared diplopic. Our results confirm that fine and coarse disparities can drive vergence eye movements, show that this aspect of binocular function is adult-like at age 5 and reveal an interesting relationship between vergence amplitudes and depth perception. This paradigm may be useful with children too young for psychophysical testing, potentially providing valuable insights into binocular visual development.

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43.4027 **Development of relative disparity processing in human infants** Holly Gerhard[1](hgerhard@gmail.com), Andrea McCall[1], Francesca Pei[1,2], Anthony Norcia[1]; [1]Psychology Department, Stanford University, [2]Department of Psychiatry, Stanford University School of Medicine

Introduction. Stereopsis is the primary cue underlying our ability to make fine depth judgments. In adults, depth discriminations are supported largely by relative rather than absolute binocular disparity, and depth is perceived primarily for horizontal rather than vertical disparities. Although human infants begin to exhibit disparity-specific responses between three and five months of age, it is not known how the relative disparity mechanisms underlying stereopsis develop. Methods. We used a sweep steady state visual evoked potential (SSVEP) paradigm to measure disparity-tuning functions for horizontal and vertical disparity by incrementally increasing disparity magnitude through 10 values. Cyclopean gratings alternating between flat and disparate at 2 Hz were presented while neural responses were recorded with a 128-channel EEG system. We extracted the maximally reliable components of the 128-channel data (Dmochowski et al., NeuroImage, 2015) and applied spectral analysis to examine neural responses at the harmonics of the disparity modulation frequency. Eight adults and 18 four-to six- month-old infants participated (mean age ± SD: 4.7 ± 0.4 mos.). Results & Conclusion. Adult SSVEP responses were characterized by two features: 1) nearly 10x more sensitivity to horizontal rather than vertical disparity (thresholds: horizontal = 0.7 arcmin; vertical = 6 arcmin), and 2) the maximally reliable component was dominated by the first harmonic (4.6x higher amplitude than the second harmonic's amplitude). Infant responses were less sensitive and also exhibited large qualitative differences: 1) the maximally reliable component was much less dominated by the first harmonic (only 1.3x higher amplitude than the second harmonic) and 2) horizontal sensitivity was only 2.5x better than vertical sensitivity. The results indicate that the specialization for horizontal, relative disparity, which is characteristic of adult stereopsis, is not yet mature in infants four to six months of age.

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43.4028 **Forced-choice disparity detection: are two or four alternatives most efficient in children?** Kathleen Vancleef[1](kathleen.vancleef@ncl.ac.uk), Jenny Read[1], William Herbert[1], Nicola Goodship[1], Maeve Woodhouse[1], Ignacio Serrano-Pedraza[2]; [1]Institute of Neuroscience, Newcastle University, [2]Department of Basic Psychology, Complutense University of Madrid

Introduction Measuring accurate thresholds in children can be challenging. A typical psychophysical experiment is usually too long to keep children engaged. However, a reduction in the number of trials decreases the precision of the threshold estimate. We evaluated the efficiency of forced-choice paradigms with 2 or 4 alternatives (2AFC, 4AFC) in a disparity detection experiment. 4AFC paradigms are statistically more efficient, but also more cognitively demanding, which might offset their theoretical advantage in small children. Methods We ran simulations evaluating bias and precision of threshold estimates of 2AFC and 4AFC paradigms. In addition, we measured disparity thresholds in 47 subjects with a 4AFC paradigm and in 75 subjects with a 2AFC paradigm, both using an adaptive weighted one-up one-down staircase (aged 4-61 years). Average threshold estimates as well as bias and precision were compared between both paradigms after 30 and 60 trials. Bias and precision was evaluated by comparing the estimates after 30 or 60 trials with the estimate after 80 trials. Results Simulations indicate a similar bias and precision for a 2AFC paradigm with double the number of trials as a 4AFC paradigm. On average, estimated threshold of the simulated data was equal to the model threshold, indicating no bias. The precision was improved with an increasing number of trials. Likewise, our data showed a similar bias and precision for a 2AFC paradigm with 60 trials as for a 4AFC paradigm with 30 trials ($p > .05$). Trials in the 4AFC paradigm took slightly longer as participants scanned more alternatives ($p < .01$). However, 4AFC still ended up faster for a given precision ($p < .001$). Conclusion Bias and precision are similar in a 4AFC task compared to a 2AFC task with double the number of trials. However, a 4AFC paradigm is more time efficient and is therefore recommended.

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43.4029 **Factors that influence depth from Panum's limiting case: An ERP analysis** Huayun Li[1,2](lihuayun99@163.com), Dongchuan Yu[1], Laipeng Jin[1], Xin Gao[3]; [1]Research Center for Learning Science, Key Laboratory of Child Development and Learning Science (Ministry of Education), Southeast University, China, [2]Department of Psychology, Centre for Vision Research, York University, Toronto, [3]Department of Mathematics and Statistics,York University, Toronto

While Panum's limiting case has been the focus of considerable study, only recently has it been discovered that, in addition to horizontal disparity, the final percept of depth is influenced by i) the vertical gradient of disparity and ii) the degree of conflict between 2D and 3D shape cues (Li et al., 2012). In this study, we evaluate correlates of neural activity in an attempt to clarify how these variables determine depth percepts in Panum's limiting case. Participants were shown a series of stereograms with variable vertical gradient and 2D/3D cue conflict. On each trial they indicated which of several percepts they observed while we recorded electroencephalograms using Scan 4.0 software. It has been shown that the amplitude of the N170 is strongly influenced by physical stimulus properties and N270 activity can be elicited by stimulus attribute conflicts. Therefore we chose to focus on these two components in our analyses. Our behavioural results replicated those of (Li et al, 2012). Our ERP analysis showed significant changes in the amplitude of the N170 component as a function of the vertical gradient; amplitudes were larger when the vertical gradient was small. There was also a significant effect of cue conflict and an interaction between the two factors on the N170. However, changes in the N270 component were only significant for the cue conflict manipulation. The mean amplitude of N270 decreased as the degree of cue conflict decreased. These results suggest that these factors affect perceived depth at different points in time: the vertical gradient disparity at an early stage of processing (N170) and cue conflict impacts processing at least at two stages (N170 and N270). Together, our behavioural and neural correlate data support the proposal that the binocular matching process underlying Panum's phenomena reflects several factors, which have different time courses.

43.4030 **Event-related potentials (ERPs) at the onset of disparity gratings** Zoltán Derzsi[1](zoltan.derzsi@ncl.ac.uk), Ghaith Tarawneh[1], Kai Alter[1], Jenny Read[1]; [1]Institute of Neuroscience, Newcastle University

Human stereopsis has relatively poor spatio-temporal resolution, due to the way disparity is encoded in V1 [1], [2]. We are investigating this with EEG. Our stimuli are dynamic random-dot stereograms. At trial onset, they depict a zero-disparity plane, but after a random latency of at least 1s, they change into a horizontal disparity square-wave grating, whose disparity reversed sign with temporal frequency TF. We randomly interleaved trials with different disparity amplitude D (0.1,0.2,0.3,0.4 deg), spatial frequency SF (0, 0.25, 0.5,1 cpd) and temporal frequency TF (2.1, 4.2, 8.3, 12.5 Hz) . After a random time between 5 and 6s, the screen was blanked and participants were asked to report whether they had perceived the grating (i.e. the disparity alternation), or whether they had perceived two solid planes. They were most likely to perceive the grating at intermediate SFs and low TFs. We measured the ERP at the Oz electrode when transitioning from the zero-disparity plane into the depth grating. We calculated the 'ERP magnitude' by integrating the absolute value of the EEG trace relative to baseline, from 0 to 1.5 seconds from the transition. Pooling from 44 sets of data, we found that the ERP magnitude is higher for stimulus parameters where participants perceive the grating ($r=0.5244$, $p< 0.0001$, Pearson correlation between ERP and probability of seeing grating, $N=64$ conditions). This may reflect the visual system's use of disparity cue for structure detection. [1] D. Kane, P. Guan, and M. S. Banks, "The limits of human stereopsis in space and time," J Neurosci, vol. 34, no. 4, pp. 1397–1408, 2014. [2] H. Nienborg, H. Bridge, A. J. Parker, and B. G. Cumming, "Neuronal computation of disparity in V1 limits temporal resolution for detecting disparity modulation," J Neurosci, vol. 25, no. 44, pp. 10207–10219, 2005.

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Eye Movements: Saccade kinematics and dynamics

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4031 Characterization and Calibration of Eye Tracking Data from Head Mounted Displays

Kamran Binaee[1](kamranbinaee@mail.rit.edu), Rakshit Kothari[1], Flip Phillips[1,2], Gabriel Diaz[1]; [1]Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology, [2]Department of Psychology & Neuroscience, Skidmore College

Eye tracking data can suffer from multiple sources of error. This is especially true for trackers integrated within virtual reality (VR) head mounted displays (HMDs). During an immersive VR experience, the quality of the data diminishes due to static and dynamic error sources. Static tracking errors arise owing to factors such as optical aberrations and display optical characteristics. These are further exacerbated by other non-linear, in-engine distortions - typically introduced to correct the projected imagery for the aforementioned distortions. While these corrections make the scene perceptually more veridical, they frequently lead to distortion in the tracker data. For an active subject in VR, the quality of the tracking data is continuously affected by physical shifts of the HMD on the observer's head. These shifts can vary from slow, slippage-related drift over the course of an experiment to paroxysmal bumps and jolts caused by contact or the inertial characteristics of the HMD/tracker combination. It is common practice for calibration procedures to establish eye-to-screen mappings, typically at the beginning of a session and fixed over the timecourse of an experiment. However, in an HMD configuration, even with periodic recalibration, data quality can quickly degrade due to the dynamic issues mentioned. Here we present a novel calibration method that corrects for static as well as dynamic distortions. We combine a static, non-linear correction with a dynamic, temporally adjusted linear correction. By incrementally sampling a small subset of ground-truth space throughout the experiment, we can continuously determine data quality as well as perform temporally specific calibration. Over the timecourse of the experiment, our static method reduces angular error by more than 50% compared to the manufacturer-provided default static calibration. Adding dynamic compensation reduces error by as much as 80%, overall. We outline our method as well as several demonstrations of real-world correction in experimental conditions.

43.4032 Viewing-position effects in meaningless object viewing

Lotje van der Linden[1](l.vanderlinden@cogsci.nl), Gregory Zelinsky[2], Françoise Vitu[1]; [1]Aix-Marseille Université CNRS, LPC UMR 7290, Marseille France, [2]Department of Psychology, Stony Brook University, New York, United States

Observers prefer to send their eyes near the centers of words and objects (preferred viewing location/PVL effect). Central landing positions, in turn, lower the chance that participants refixate the word or object (optimal viewing position/OVP effect) and prolong the duration of the first fixation (inverted OVP/I-OVP effect). Researchers debate whether these viewing-position effects reflect intentional eye-movement behavior that adapts to ongoing word/object processing, or automatic visuomotor tendencies that occur regardless of word/object content. In favor of the latter account, all viewing-position effects were found to generalize to the scanning of meaningless letter strings. But does this also hold for meaningless non-object viewing? The current study answered this question by comparing eye-movement behavior towards real objects versus meaningless non-objects. We reasoned that similarities would reflect visuomotor constraints, whereas differences would reflect higher-level processing. Participants performed a saccade-target task towards isolated stimuli that were presented at 3° or 5° in the periphery. We measured initial landing positions, and how these influenced fixation durations and refixation behavior. Objects were Hemera pictures that were matched for pixel area (mean width: 1.51°; mean height: 1.44°). Non-objects were similarly-sized discs that were matched to the corresponding real objects in pixel area and texture (using a texture-synthesis algorithm), and therefore had no semantic content. We found that for both objects and non-objects, initial landing positions did not deviate significantly from the stimulus' center, reflecting a central PVL. Furthermore, we found that refixation probability increased (OVP), and initial-fixation duration decreased (I-OVP), with increasing distance between the initial landing position and the stimulus' center. This was the case for both objects and non-objects, suggesting that OVP and I-OVP effects also generalize to meaningless non-object viewing. We conclude that these viewing-position effects are indeed universal tendencies that reflect low-level visuomotor mechanisms instead of ongoing object-/ word-recognition processes.

43.4033 Contextual saccade adaptation as a tool to investigate sequential saccades.

Rakesh Nanjappa[1](rnanjappa@sunyopt.edu), Reza Azadi[1], Robert McPeek[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry, New York

Saccade adaptation can be contextual; meaning that saccade gain for the same retinotopic target location can differ depending on the context. In this study we used reflexive and sequential scanning saccades as contexts in order to investigate whether saccadic sequences are processed differently from single saccades. In Experiment 1, subjects were instructed to perform either a single downward-vertical saccade when the initial fixation point was presented at the center of the monitor (reflexive trials), or a sequence of two saccades when the fixation point was located on the right side of the monitor (scanning trials), where the second saccade of the scanning trials was the same as the saccades in the reflexive trials. The scanning and reflexive trials were interleaved. After a baseline phase, in the adapting phase, we induced opposite saccadic adaptation (gain-increasing and gain-decreasing) in the reflexive and scanning trials using a double-step procedure. The experiment terminated with a post-adapting phase, similar to the baseline. Results showed a gradual saccadic gain change, in opposite directions, for scanning and reflexive trials. The reflexive and scanning saccadic amplitudes at the end of the adapting phase and even in the post-adapting phase were significantly different, indicating strong contextual saccade adaptation. Experiment 2 was similar to Experiment 1, except that we replaced the reflexive trials with sequential saccades from the left-side of the monitor and tried to induce contextual saccade adaptation in the second saccade of the two different saccade sequences. Surprisingly, we did not find any significant shifts in saccadic gain in Experiment 2. The fact that saccades in the reflexive and scanning contexts can be adapted independently provides evidence that these two types of saccades are planned and performed differently. However scanning saccades from two different sequences cannot be adapted in opposite directions, suggesting that adaptation is transferred between them.

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43.4034 Gain-increase saccadic adaptation is enhanced by the use of constant retinal error feedback

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Introduction: Saccadic accuracy is maintained by sensorimotor adaptive mechanisms that continually adjust movement gains when faced with consistent errors. It is known that generally the saccadic system is resistant to increasing its gain. This study investigates whether gain-increase saccadic adaptation can be improved by using a constant "retinal error" (RE) instead of the conventional "spatial error" (SE). Because adaptation is driven by the dynamic comparison of actual and predicted postsaccadic errors, we hypothesized that there would be an increased saccadic gain change in the RE compared to the SE condition. Methods: Eleven visually-normal observers performed two experimental sessions. Each session included three blocks: preadaptation, adaptation, and postadaptation during binocular viewing. In the control SE condition, the target appeared at ±10° followed by a 3° step in the same direction during the primary saccade. In the RE condition, the second step always appeared 3° away from the trial-by-trial real-time eye position after the primary saccade. Eye movements were tracked with the EyeLink II at 250 Hz. Percentage saccadic gain change and percentage gain retention from baseline were calculated. Results: All participants but one increased their saccadic gains substantially. Mean percentage gain change was higher in the RE (58±22%) compared to the SE (38±13%; p=0.01) condition. Adaptation retention was augmented in the RE condition for six out of ten participants, however the mean percentage retention was not statistically significant between conditions (RE=36±15%, SE=27±19%; p=0.26). Conclusions: This study provides a novel comparison of the constant retinal error and the conventional spatial error in driving gain-increase saccadic adaptation. The greater adaptation magnitude during the RE condition corroborates previous findings that a consistent disparity between the actual and predicted error plays a major role in driving saccadic adaptation. We intend to implement this enhanced technique in the future to study gain-increase saccadic adaptation in amblyopia.

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Foundation for Innovation (CFI), the John and Melinda Thompson Endowment Fund in Vision Neurosciences and the Department of Ophthalmology and Vision Sciences at The Hospital for Sick Children.

43.4035 Quantifying the Spatiotemporal Properties of Saccade Averaging Shane Kelly[1](skelly18@masonlive.gmu.edu), Weiwei Zhou[1], Sonia Bansal[1], Matthew Peterson[1], Laurence Bray[1], Wilsaan Joiner[1]; [1]George Mason University

Humans produce quick eye movements (saccades) to redirect the fovea and obtain visual information about the environment. Saccades are guided by bottom-up information, such as size or luminance (Deubel et al., 1984), and top-down information, such as task goals (Herwig et al., 2010). In some cases when two targets are in close proximity, up to a 30° separation, saccades are directed to an intermediate location (saccade averaging, Coren & Hoenig, 1972), with the highest incidence of averaged movements occurring when reaction time is low (Chou et al., 1999). However, the exact spatial and temporal relationships that contribute to saccade averaging are currently unknown. Recently, Haith and colleagues (2015) examined intermediate (averaged) movements during a time restricted visually guided reaching task. The target shifted at different times before reach onset, providing limited time to re-prepare the movement plan. When re-preparation time was small, the movement was directed to the initially cued target. However, as this time increased, the authors observed intermediate movements aimed between the two targets. Importantly, this time was modified by the spatial distance between competing goals. The authors suggest that these intermediate movements reflect an adaptive behavior of the motor system when the goal of a movement is ambiguous. Here, we applied the same paradigm and framework to saccadic eye movements. We found the re-preparation time that resulted in intermediate movements increased with the spatial distance of competing targets (70ms, 92ms, and 113ms, for 15o, 30o and 45o of separation, respectively). In addition, the variability of this relationship changed as a function of the target shift, with the transition between the two targets becoming sharper with distance. Collectively, our results demonstrate that saccade averaging, similar to reaching movements, depends on the amount of time to prepare the movement plan and the spatial separation of competing movement goals.

43.4036 Saccade trajectories deviate away from spatial, and not retinal, location of nearby tactile distractors David Aagten-Murphy[1](david.aagtenmurphy@gmail.com), Luca Wollenberg[1], Martin Szinte[1], Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany

The abrupt appearance of a stimulus typically elicits a reflexive saccade towards it. However, when individuals are voluntarily moving their eyes to another location, the appearance of this distractor stimulus can instead cause the trajectory of the saccade to curve. Here we studied how visual and tactile distractors influence the trajectories of eye-movements in a double-step task. Participants made two consecutive saccades (a horizontal followed by a vertical) during which a visual (LED) or tactile (vibration to the index finger) distractor could occur either before or after the first saccade. The results confirmed that, as with a visual distractor, the occurrence of a tactile distractor prior to an eye-movement caused the trajectory of the saccade to curve away from the distractors position. Additionally, with conditions in which the spatial and retinal locations of where the distractor had been shown were dissociated, we were able to demonstrate for both modalities that saccades curved away from the spatial position. We also examined whether crossing the hands, so that a tactile distractor on the left finger would occur on the right side of space and vice versa, influenced the direction of the curvature. In contrast to the curvature found when the hands were canonically arranged, in the crossed hands condition tactile distractors caused attenuated or no curvature of the saccade. Overall these results suggest that although both visual and tactile distractor signals compete with the representation of the saccade target within an oculomotor map, the representation for tactile distractors may not fully compensate for irregular limb position.

43.4037 Curvature is a Characteristic of Saccades in Planned Sequences Kevin Willeford[1](kwilleford@sunyopt.edu), Reza Azadi[1], Robert McPeek[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry, New York

Prior evidence suggests sequential saccades are processed in parallel: secondary saccades occur with shorter latencies, and attention is allocated to secondary spatial locations prior to primary movement execution. However, it remains unclear whether such saccades are planned independently or as part of a sequence. We measured saccadic curvature in sequential saccades to address this question. In this study, curvature of vertical saccades was measured prior to or following horizontal movements, and trials with single vertical saccades served as controls. In Experiment 1, the offset of a fixation point and onset of three horizontally-aligned targets signaled subjects to initiate sequences of two saccades. The first was vertically directed towards the middle target; the second was cued to be either rightward or leftward by a line on the fixation point. Analyses revealed that primary saccades tended to curve away from the direction of the subsequent saccade. In Experiment 2, subjects made a vertical saccade to a target, followed by a second saccade to either a near or far rightward target. We found that the curvature of the initial saccade away from the subsequent saccade was more pronounced when the second saccade had a larger amplitude. In Experiment 3, the fixation point was presented on either the right- or left-hand side, and two vertically-aligned targets were shown on the screen following fixation point offset. Thus, sequences consisted of primary horizontal and secondary vertical movements. We found that the secondary saccades curved in the direction of the antecedent saccades. In all three experiments, there were significant correlations between saccadic curvature of the right and left eyes; however, no significant correlations between curvature and either inter-saccadic interval or latency were found. These findings indicate that saccadic curvature is modified by characteristics of both antecedent and subsequent saccades, suggesting that sequential saccades are not planned independently.

Acknowledgement: NIH EY014885

Eye Movements: Saccade mapping and timing

Monday, May 16, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.4038 A new approach to double step saccades: random stimulus displays and 2D vector analysis. Paul Zerr[1](p.zerr@uu.nl), Katharine Thakkar[2], Siarhei Uzunbajakau[1], Stefan Van der Stigchel[1]; [1]Helmholtz Institute, Department of Experimental Psychology, Utrecht University, NL, [2]Department of Psychology, Michigan State University, East Lansing, Michigan, USA

In saccade sequences endpoint errors pose a problem for subsequent saccades in the absence of visual feedback. Compensation for endpoint variability has previously been demonstrated in double step saccades (DSS; e.g. Joiner et al., 2010) and is thought to rely on a copy of the saccade motor vector (corollary discharge; CD). However, these studies typically use highly repetitive stimuli (e.g. one or few identical target vectors). While this eases analysis, it calls into question the generalizability of the findings due to the high target predictability. We present a new, random walk based DSS paradigm (random target vector amplitudes and directions) and a direct way of analyzing this data to provide a more complete, realistic and generalizable description of error compensation in saccade sequences. We regressed the difference vector between the endpoint of the second saccade and the endpoint of a second saccade that does not take first saccade error into account on the vector necessary for full compensation. This provides a direct and complete quantitative estimation of error compensation in DSS's. Data modeling verified the validity of the paradigm and data analysis method. As expected we observed error compensation lower than but comparable to traditional experiments. We also employed this paradigm to replicate previous findings that showed compensation for systematic undershoots after specific-vector saccade adaptation. This indicates that the CD signal used for estimating post-saccadic target location is taken downstream from the site of adaptation (Tanaka, 2003). Utilizing the random walk paradigm for saccade adaptation by Rolfs et al. (2010) together with our random walk DSS paradigm we now also demonstrated this for global saccade adaptation. We developed a new, generalizable DSS paradigm with and successfully employed it to verify, replicate and extend previous findings, demonstrating that endpoint errors are compensated for even in variable stimulus displays.

43.4039 Bimodal latency distribution and distractor effects in Express Saccades in humans. Jessica Heeman[1,2](j.heeman@vu.nl), Stefan Van der Stigchel[2], Jan Theeuwes[1]; [1]Department of Cognitive Psychology, Vrije Universiteit Amsterdam, The Netherlands, [2]Helmholtz Institute, Department of Experimental Psychology, Utrecht University, The Netherlands

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It is well known that under specific conditions, saccades can be made with extremely short latencies (about 110 to 130 ms). These so-called Express Saccades (ES) have been observed in animals showing two separate peaks in the saccade latencies distributions. Up till now, separate peaks in the distribution have not been observed in human observers. In two experiments we investigated the saccade latency distribution while examining two well-known target-distractor interactions. We examined the Global Effect (GE) which occurs when a distractor is presented in close proximity of the target. Typically, saccades tend to land at a location between target and distractor. In addition we examined the Remote Distractor Effect (RDE), an effect which describes the longer saccade latencies when a distractor is presented further away from a target. In both experiments participants made saccades to a sudden onset target. In some trials the target was accompanied by a distractor close or remote from the target. A gap-paradigm ensured a high percentage of low latency saccades. In Experiment 1, participants were given a 100% valid cue and a warning tone to indicate the impending target and its location and qualitative feedback on the response time. In Experiment 2 the timing was identical but we presented no cue, no warning toine and neutral feedback was provided. The paradigm triggered high percentages of ES. Extraordinarily, the latency distribution in Experiment 1 showed two distinct, separate peaks. This suggests that, as has been suggested based on animal studies, a separate process that results in ES is involved in the processing of early visual information in human observers. In addition, results show a GE and a RDE, even for the fastest visually triggered saccades. This indicates that endogenously prepared ES are not immune to exogenous influences and are moderated by early visual input.

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43.4040 **Saccadic latency and choice in a concurrent random interval reinforcement schedule.** Cécile Vullings[1](cecile.vullings@gmail.com), Laurent Madelain[1,2]; [1]Univ. Lille, CNRS, CHU Lille, UMR 9193 - SCALab - Sciences Cognitives et Sciences Affectives, F-59000 Lille, France, [2]Aix Marseille Université, CNRS, Institut de Neurosciences de la Timone, UMR 7289, Marseille, France

Conventional decision models view reaction time as a consequence of the duration of decision-making process. However, some studies have shown that reaction time distributions may be strongly affected by reinforcement contingencies (Madelain et al., 2007). Here, we probe the possibility to voluntarily control saccadic latencies in a choice paradigm. Three subjects (including the two authors) tracked a visual target stepping horizontally by 10 deg between two fixed locations on a screen. Any trial with saccadic latencies greater than 300 ms or shorter than 80 ms was interrupted. Using the first and last quartiles of individual baseline latency distributions, we first defined two classes, i.e. "short" and "long" saccadic latencies, respectively. We then concurrently reinforced each type of latencies in random interval reinforcement schedules: "short" and "long" latencies were reinforced with three different sets of probabilities such that the relative ratio of reinforcing "short" latencies was either 9/1, 1/9 or 1/1. After training (20 800 trials), we observed bimodal latency distributions –with a peak for "short" and another for "long" latencies– for two subjects and to a lesser extent for the third subject. To further probe the extent of control over saccadic latencies, we then analyzed the data using the generalized matching law (Baum, 1974) –which states that the relative proportion of choices made to an option matches the relative proportion of reinforcers earned from that option. We found an almost perfect match between the relative proportion of "short" and "long" latencies and the relative obtained reinforcement for two subjects (sensitivities were equal to 0.95 and 0.87) and typical undermatching parameter for the third one (sensitivity = 0.58). These results indicate that saccades may be allocated in time following the reinforcement contingencies in force, which support the idea of a voluntary control of saccadic reaction time.

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43.4041 **Perception of Saccadic Reaction Time in humans** Valentina Vencato[1,2](vvale68@gmail.com), Laurent Madelain[1,2]; [1]Univ. Lille, CNRS, CHU Lille, UMR 9193 - SCALab - Sciences Cognitives et Sciences Affectives, F-59000 Lille, France, [2]Aix Marseille Université, CNRS, Institut de Neurosciences de la Timone UMR 7289, Marseille, France

Saccadic eye movement are widely used to investigate underlying decision processes and numerous quantitative models have been proposed to account for changes in saccade reaction time (SRT) distributions, often in conjunction with neurophysiological data. Although they are typically short – often ranging from 100 to 400 ms – and conventionally regarded as a consequence of the duration of decision-making process, previous findings showed that reinforcement contingencies modulates SRT distributions (Madelain et al. 2007) which raises the possibility of a voluntary control of SRTs. Because some minimal perception must be necessary for any voluntary response we ask whether it is possible to accurately perceive such short reaction time. We first collected baseline SRTs in three subjects tracking a stepping visual target. For each subject we computed four SRT classes using the four quartiles of the individual baseline SRT distributions (individual example of SRTs class intervals: 80-182ms; 183-212ms; 213-237ms; 238-400ms). Subjects were then trained to discriminate their SRTs: after each saccade they had to classify the saccade latency in a 4 AFC task and received a feedback indicating the correct answer. Results indicate that, after intensive training, subjects could overall classify their SRT with up to 42% correct responses, well above chance level (25%). Moreover, data showed that for each of the four latency classes the probability of a correct response was systematically higher ($p< 0.01$) than for any other response. In the same way, for each of the four discrimination responses the probability of SRT falling in the correct quartile was systematically higher ($p>0.01$) than for any of the 3 other classes. Altogether these results are the first to indicate that human subjects are able to discriminate their own saccade latencies, albeit imperfectly. The precision and extent of this ability remains to be experimentally probed.

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43.4042 **Phase-locking of behavioral fluctuations to microsaccade generation** Joachim Bellet[1,2](joachim.bellet@cin.uni-tuebingen.de), Ziad Hafed[1]; [1]Werner Reichardt Centre for Integrative Neuroscience, Tuebingen University, 72076 Tuebingen, Germany, [2]International Max Planck Graduate School of Behavioral and Neural Sciences, Tuebingen University, 72076 Tuebingen, Germany

Our eyes are in constant motion even during periods of attempted gaze fixation. Among the types of fixational eye movements that are known to occur are microsaccades, which are tiny saccades (typically < 1° of visual angle) occurring 1-3 times per second. Even though visual processing has already been shown to be modulated close to the time of microsaccades, it is not clear how microsaccade generation might influence longer-term fluctuations in brain activity and behavior. Here we show that visual processing is significantly affected even several hundreds of milliseconds after a microsaccade has occurred, and this happens because microsaccades reset the phase of ongoing brain oscillations. We conducted psychophysical experiments in which subjects had to make a targeting saccade, as fast as possible, towards a peripheral stimulus that was experimentally presented at different times after a microsaccade. Eight subjects were instructed fixate a circular white dot (0.1° diameter) in the middle of a gray screen. Fixation duration was randomized between 300 and 3000 ms. After this duration, the fixation dot disappeared and, simultaneously, a 1°-diameter white target appeared 5° to the right or left of fixation. We investigated whether the relative time and direction of the microsaccade preceding target appearance could influence reaction time (RT) to the target. Mean RT varied in a rhythmic fashion depending on when the stimulus was presented relative to a microsaccade. The first 400 ms following a microsaccade revealed strong oscillations in RT (~15 Hz), in the hemifield towards which the microsaccade was directed to; the next 400 ms presented similar (albeit lower-frequency) oscillations (~10 Hz), but this time in the opposite hemifield. Our results suggest that visual processing is subject to oscillations that are phase-locked to the time of microsaccade generation, and that these oscillations are strongly dependent on microsaccades direction.

43.4043 **Microsaccades during reading** Norick Bowers[1](nbowers2@bu.edu), Michele Rucci[1], Martina Poletti[1]; [1]Department of Psychological and Brain Sciences, Boston University

Background. Extensive research has focused on the control of saccades during reading. However, very little is known in this context about microsaccades (saccades< 0.5 deg), i.e., whether they occur and how they shift the gaze. Using new methods for precisely localizing the line of sight, we recently showed that in high acuity tasks microsaccades precisely position the preferred retinal locus, the tiny region of maximum acuity within the foveola (Ko et al, 2010; Poletti et al, 2013). These findings raise the possibility that microsaccades may also play a role in reading. Methods: Observers (N=10) were instructed to read 10th grade passages of text and answer questions regarding their content. Eye movements were recorded by means of a high resolution DPI eyetracker. Gaze-contingent calibrations were used to accurately localize the preferred retinal locus. Results: Microsaccades occur during reading: the average rate across all subjects was 18 microsaccades per minute. Interestingly, their characteristics differed from those measured when fixating on a marker. During fixation, microsaccades had approximately equal probability to shift the gaze to the left or to the right, and a considerable number (~32%) possessed vertical components. In contrast, during reading, most microsaccades (61%) directed the gaze leftwards and only 16% vertically. Therefore, microsaccades primarily relocated the gaze backward on the text, most of them just 2-3 letters back from the end of long words. Further analyses showed that this pattern of microsaccades differed significantly from what would be obtained by chance. Conclusion: Our results show that microsaccades occur and are controlled during reading. It is well known that the perceptual span normally extends asymmetrically toward the reading direction. Microsaccade backward shifts could compensate for this asymmetry.

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43.4044 Sensorimotor transformation for antisaccades requires dissociable facilitatory and inhibitory components Donatas Jonikaitis[1], Saurabh Dhawan[2], Nina Hanning[2], Heiner Deubel[2]; [1]Howard Hughes Medical Institute, Stanford School of Medicine, [2]Allgemeine und Experimentele Psychologie, Ludwig-Maximilians-Universität München

The anti-saccade task, in which participants have to avoid a reflexive response towards a visual stimulus and make a voluntary response away from it instead, is a classic task to investigate flexible control of behavior. However, earlier work has show enhanced visual and neural responses at the visual stimulus and saccade target locations, which is at odds with the idea that anti-saccade task requires inhibition of reflexive responses. In the current study we developed a memory-guided anti-saccade task in which participants made pro and anti-saccades after variable delays from the visual stimulus onset. To probe for facilitatory and inhibitory motor biases, we measured the latencies of reflexive saccades to different locations in space while participants performed the task. The results demonstrate, for the first time, that the anti-saccade task leads to the formation of a spatially specific inhibitory bias at the visual stimulus location and a facilitatory bias at the anti-saccade goal. Importantly, these motor biases were accompanied by sensory facilitation at both, the visual stimulus location and the anti-saccade goal, indicating that motor inhibition is exclusive to the oculomotor system. Our findings indicate that the anti-saccade task evokes both facilitatory sensory gating mechanisms and suppressive oculomotor mechanisms. Further, they can explain earlier reported paradoxical findings and suggest a two-level mechanism for the anti-saccade produc

43.4045 Effect of allocentric cues on primate gaze behaviour in a cue conflict task Jirui Li[1,2,3,4](ljr@yorku.ca), Amir Sajad[1,2,3,4], Robert Marino[5], Xiaogang Yan[1,2,3], Saihong Sun[1,2,3], Hongying Wang[1,2,3], Douglas Crawford[1,2,3,4]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada M3J 1P3, [2]Canadian Action and Perception Network, [3]Departments of Psychology, Biology, and Kinesiology and Health Sciences, York University, Toronto, Ontario, Canada M3J 1P3, [4]Neuroscience Graduate Diploma Program, York University, Toronto, Ontario, Canada M3J 1P3, [5]Centre for Neuroscience Studies, Queen's University, Kingston, Ontario, Canada K7L 3N6

The visual system can remember the location of a peripheral target relative to the self (egocentric coordinates) or to an external landmark (allocentric coordinates). The relative influence of each reference frame have been examined for reach (Byrne & Crawford, J. Neurophysiol. 2010), but have not been systematically explored in the gaze control system. Here, we utilized a cue conflict paradigm to assess the effect of allocentric cues on gaze behaviour in the rhesus monkey. One monkey was trained to maintain central fixation while a target was presented for 100ms in one of eight radial directions, along with an allocentric cue presented at one of four oblique directions 11º from the target. This cue was the intersection of two horizontal/vertical lines spanning the visual field. After a 100ms delay, a mask was shown for 100ms during which the allocentric cue was displaced by 8° in one of eight radial directions. After a second delay of 300-700ms, the fixation point extinguished, acting as a 'go' signal for a head-unrestrained saccade towards the remembered target. The monkey did not look toward the original target or the cue location, but rather toward a point shifted partially toward a virtual target defined relative to final cue location (i.e., in allocentric coordinates). Overall, there was a significant ($P < 0.01$) allocentric shift in gaze endpoints relative to controls (with no cue shift), with a mean gain of 0.27 (where 0 = no shift and 1.0 = complete shift). In addition, the cue had a significantly greater effect when it shifted away from centre in the direction of the saccade ($P < 0.01$) and when it shifted towards the original target ($P < 0.01$). These preliminary findings suggest that internal representations of gaze targets are weighted between egocentric and allocentric cues, and this weighting is further modulated by specific gaze parameters.

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Multisensory Processing: Vision and hearing, perceptual processes

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4046 ON and OFF channels in auditory-visual integration Cesare Parise[1](cesare.parise@uni-bielefeld.de), Martin Banks[2], Marc Ernst[1]; [1]University of Bielefeld, [2]University of California, Berkeley

Unisensory information is of course processed before integration with signals from other senses. Sensory input in the visual and auditory systems are segregated into ON and OFF pathways that respond differentially to changes in input intensity. Specifically, an increase in intensity leads to an increment in neural response in the ON pathway, and decrement in the OFF pathway. The opposite occurs with an intensity decrease. We investigated how humans combine auditory-visual stimuli that consist of step changes in intensity. Subjects made temporal-order judgments. Stimuli consisted either of increments (ON stimuli) or decrements (OFF stimuli) in intensity over time. ON and OFF stimuli were paired in all possible combinations. In some pairings, the stimuli both increased or decreased in intensity. In other pairings, one increased while the other decreased. Subjects reported the modality that seemed to change first. Recently, we developed a model in which multisensory integration relies on elementary units analogous to the motion-energy units observed in insect visual systems. In its original form, the model consisted only of ON channels, so an increment in intensity in one modality paired with a decrement in the other would produce an inversion of perceived temporal order reminiscent of the "reverse phi" effect in visual motion perception. The results from the temporal-order judgment task showed that subjects could accurately identify the temporal order of the two signals even when the intensity in the two modalities changed in opposite directions. This suggests that unisensory information is separately processed in ON and OFF channels, yielding an estimate of the time of change without regard to sign, before the information is integrated. A simple model in which unisensory information is first segregated into ON and OFF channels, low-pass filtered, and then recombined before feeding into an energy unit yields behavior consistent with our experimental observations.

Acknowledgement: 7th Framework Programme European Project

43.4047 Recalibration to audiovisual simultaneity: Insights from a temporal bisection task Ljubica Jovanovic[1], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs, Département d'études cognitives, Ecole Normale Supérieure

People can adapt to a fixed temporal lag between audiovisual events, resulting in changes in perceived simultaneity (Fujisaki et al., 2004, Nat Neurosci). Our aim was to investigate whether one modality recalibrates the other in this adaptation. We used a temporal bisection task in which three consecutive events were presented. Participants judged if the middle event was closer in time to the first or the last one. Visual events were flashed white discs and auditory events were 2kHz pure tone. To reduce the saliency of the tones, white auditory noise was presented in the background during each trial. Before running the bisection task, participants were presented with 100 audiovisual events where the visual event lagged by 100ms the auditory. We contrasted four conditions: two unimodal and two multimodal. Unimodal conditions consisted of three purely visual or auditory events. In a multimodal condition, the first and the third event were either auditory or visual and the middle event was audiovisual with a lag identical to the adaptation phase. Points of indifference (PI, ratio of physical durations of first over second intervals leading to equal perceived durations of first and second intervals) were calculated separately for the four conditions. Across participants in the unimodal conditions, PIs were typically less than 1 and different for vision and audition. We reasoned that if vision recalibrates audition, the PI for the multimodal auditory condition should be shifted towards the unimodal visual PI, and conversely if audition recalibrates vision. We found shifts in PI for both multimodal conditions relative to the corresponding unimodal conditions, suggesting partial recalibration of both modalities. This result is understandable within our setup where both modalities had comparable sensitivities in the bisection task. In summary, the temporal bisection task appears to be a valuable tool to assess recalibration to multisensory lags.

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43.4048 Cross-modal motion aftereffects induced by complex auditory stimuli

Katherine Tregillus[1](kemtregillus@gmail.com), Alissa Winkler[1], Fang Jiang[1]; [1]Department of Psychology, University of Nevada, Reno

It has been demonstrated that motion aftereffects can transfer across perceptual modalities. For example, the motion aftereffect induced by a visual stimulus can affect the perceived motion direction of an auditory stimulus. Although cross-modal adaptation has been demonstrated from the visual to the auditory domain, aftereffects have not been consistently reported from the auditory to the visual domain. Previous research has often used simple auditory motion stimuli that contained a single motion cue. The current study utilized a more complex, naturalistic auditory motion stimulus. It contained multiple motion cues including inter-aural time differences, inter-aural level differences, and Doppler shifts that simulated an auditory stimulus traveling along the fronto-parallel plane. Participants were asked to judge the direction of random dot kinematograms (RDK) after adapting to auditory motion. The coherence levels of the visual motion stimuli (RDKs) were individually predetermined using a staircase procedure. We fit each participant's data with normal cumulative distribution functions and estimated the points of subjective equality (PSE). The PSEs were compared between the rightward and leftward adaptation conditions. We observed a consistent trend indicating cross-modal aftereffects on visual motion following adaptation to auditory motion. Our results suggest that a more complex auditory motion stimulus may have greater ability to induce cross-modal aftereffects.

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43.4049 Audiovisual Rate-Discrimination Depends on Both Spatial and Temporal Cues for Integration

Shannon Locke[1](sml726@nyu.edu), Michael Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Spatiotemporal correlation is important for driving multisensory integration as it indicates the signals derive from a common source. However, it has been shown that sequences of visual flashes and auditory clicks are optimally integrated regardless of the temporal correlation between the sequences in a rate-discrimination task (Raposo et al., J. Neurosci., 2012). Yet, in a localization task with similar stimuli, only synchronous click-flash sequences were integrated optimally (Parise et al., Curr. Biol., 2012). Thus, the conditions for multisensory integration of audiovisual sequences appear to be task-dependent. We examined both the spatial and temporal conditions necessary for optimal integration in rate-discrimination to better understand this phenomenon. Observers judged the rate of a comparison stimulus relative to a multisensory 8 Hz standard. Rate-discrimination thresholds were estimated for visual-only, auditory-only and multisensory conditions in each session using interleaved adaptive procedures. There were four multisensory conditions: Sequences were spatially congruent or not, and temporally synchronous or not. Spatial congruence: The auditory stimulus was either from a centrally placed speaker beneath the visual stimulus or a speaker 53 deg to the right. Temporal sequences were either synchronous or generated independently for each modality. Visual stimuli: Gaussian blurred white disks (2.5 deg SD). Auditory stimuli: bandpass noise (200 Hz – 10 kHz). Event duration: 17 ms. Stimulus duration: 2000 +/- 250 ms. Most observers were indistinguishable from optimal (based on measured single-modality JNDs) when audiovisual stimuli were spatially congruent and temporally synchronous. In all other conditions, most observers were sub-optimal. Therefore, observers relied on temporal cues in the decision to integrate or not, unlike the findings of Raposo et al. (2012), as well as spatial cues (not previously demonstrated). Differences between the two rate-discrimination studies will be discussed (including: sequence generation methods, detectability of stimuli, training). We suggest that multisensory integration for audiovisual sequences is not task-dependent.

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43.4050 Audiovisual integration and spatial alignment in azimuth and depth.

Nathan Van der Stoep[1](n.vanderstoep@uu.nl), Tanja Nijboer[1,2], Stefan Van der Stigchel[1]; [1]Utrecht University, Department of Experimental Psychology, Helmholtz Institute, Utrecht, The Netherlands, [2]Brain Center Rudolf Magnus, and Center of Excellence for Rehabilitation Medicine, University Medical Center Utrecht and De Hoogstraat Rehabilitation, The Netherlands

Sound and light that originates from the same spatial location tends to be integrated into a unified percept, whereas it is less likely that this information is integrated when it originates from different locations. This 'principle of spatial alignment' has been demonstrated in several neurophysiological and behavioral studies of audiovisual integration but has only been investigated in a single depth-plane. In the current study it was investigated how spatial alignment of auditory and visual information in azimuth and in depth modulated audiovisual integration using a redundant target effect (RTE) task. The participants were instructed to respond as fast as possible to unimodal visual, unimodal auditory, and audiovisual stimuli that appeared to the left and the right of fixation, but to withhold their response when a stimulus was presented at the central location. Visual stimuli were presented in near space but only varied in azimuth while auditory stimuli were presented both in near and far space and varied in azimuth. On multisensory trials visual stimuli were accompanied by an auditory stimulus that was aligned or misaligned in azimuth and aligned or misaligned in depth. Each participant was well able to localize the auditory stimuli in azimuth and in depth as indicated by a separate six-alternative forced-choice auditory localization task that took place before the RTE task. The amount of multisensory response enhancement (MRE) and race model inequality (RMI) violation was compared between the different spatial alignment conditions to see how audiovisual integration was affected by spatial alignment in azimuth and depth. The amount of MRE and RMI violation was significantly modulated by spatial alignment of sound and light in azimuth, but not by spatial alignment in depth. These results indicate that when monitoring spatial alignment in depth is task-irrelevant, spatial alignment in azimuth is sufficient for evoking audiovisual integration.

43.4051 A Crossmodal Roelofs Effect Reveals a Shared Frame of Reference for Visual and Auditory Localization

Jeffrey Peterson[1](j-peters7@uoregon.edu), Paul Dassonville[1]; [1]Department of Psychology & Institute of Neuroscience, University of Oregon

When a large frame is presented offset from an observer's objective midline, the observer's egocentric reference frame becomes distorted, with the perceived midline biased in the direction of the frame's offset (Dassonville & Bala, 2004). This distortion, in turn, causes mislocalizations of both the frame (the Roelofs effect, Roelofs, 1936) and visual probes located within the frame (the induced Roelofs effect, Bridgeman et al., 1997a). A search for an auditory analogue of the Roelofs effect indicated that auditory contextual information is capable of causing a mislocalization of auditory probes (Bridgeman et al., 1997b), but these results have been interpreted as being contrast effects occurring in an allocentric reference frame, rather than being caused by a distortion of the egocentric reference frame (Getzmann, 2003). If an auditory Roelofs effect does not in fact exist, it is unclear whether this is because auditory contextual information is incapable of causing a distortion of the egocentric reference frame, or because auditory probes are localized within a reference frame that is immune to the effects of Roelofs-inducing contextual information, whether visual or auditory in nature. To address this ambiguity, we employed a crossmodal Roelofs design in two experiments: 1) localization of auditory probes in the presence of an offset visual frame; and 2) localization of visual probes in the presence of an offset auditory scene. Auditory and visual probes were found to be equally susceptible to the induced Roelofs effect caused by a visual frame, supporting models of a shared egocentric reference frame for encoding the location of stimuli in both sensory domains. In contrast, the lateral offset of an auditory scene had no effect on visual localization, indicating that auditory context, unlike visual context, does not contribute to the establishment of the egocentric reference frame.

43.4052 Disappearance of co-occurring biases among multiple features for contrast judgments

Erika KUMAKURA[1](kumakura@l.u-tokyo.ac.jp), Kazuhiko YOKOSAWA[1]; [1]Graduate School of Humanities and Sociology, The University of Tokyo

When a sensory feature itself is too ambiguous to judge its magnitude, we can interpret it by relying on prior knowledge; co-occurrence relation with other sensory features. For example, if one must judge the brightness of outdoor illumination (bright versus dark), the subjective brightness of illumination is very ambiguous. Depending upon co-occurring features such as time of day (daytime or night), one might be biased to judge the illumination as either bright or dark. This study investigated whether biasing effects of several co-occurring features on participants' judgments of a target feature would disappear in situations where the target feature and co-occurring features had no correlation. Subjects had to judge whether the visual contrast of a Gabor patch was high or low while ignoring the visual orientation of this patch and ignoring the concurrent sound of a pure tone. The contrast of patches was mostly high or low, sometimes medium. Over trials, the probabilities of co-occurrence between visual contrast and visual orientation (rightward or leftward) and that between

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contrast and auditory loudness (loud or soft) were both controlled. We created three conditions: uncorrelated contrast-orientation, uncorrelated contrast-loudness, and uncorrelated contrast-orientation/contrast-loudness conditions. In each condition we examined whether subjects' judgment of visual contrast in high and low alternatives to medium contrast changed. If subjects used co-occurring features in judging visual contrasts, then judgments for mid-contrast should not be chance level; they should show systematic biases responding for uncorrelated relationships between target contrast and patch orientation and/or those between target contrast and tone loudness. Results indicated that participants' mid-contrast judgments were biased both by visual orientation and by tone loudness initially. However, on later trial, judgments of mid-contrast targets did not differ significantly from chance levels. These findings suggest that the influence of co-occurring features on visual contrast percepts could disappear.

43.4053 Audiovisual "Invisible Rabbit": Auditory Suppression of Visual Flashes in Spatiotemporal Stimuli Monica Li[1](mli@caltech.edu), Noelle Stiles[1,4], Carmel Levitan[2], Yukiyasu Kamitani[3], Shinsuke Shimojo[1]; [1]Biology and Biological Engineering, MC 139-74, California Institute of Technology, Pasadena, CA, 91125, USA, [2]Cognitive Science, Occidental College, 1600 Campus Rd, Los Angeles, CA 90041, [3]Graduate School of Informatics, Kyoto University, Kyoto 606-8501, Japan

Background: In general, vision dominates perception in the spatial domain, and audition in the temporal. What happens with conflicting spatiotemporal stimuli? We show that, by optimizing the signal-to-noise ratio, audition can suppress vision, postdictively (i.e. retroactively). Methods: Three flashes (13 ms each, total stimulus duration 145 ms) were presented at a 10-degree eccentricity (below fixation) with apparent left-to-right horizontal motion, where the first and last flashes were paired with 7 ms beeps [3F2B]. As controls, stimuli with no beeps [3F0B] or beeps paired with each flash [3F3B] were presented. Participants reported the perceived number of flashes. A second experiment tested the illusion's postdictive aspect with two added stimulus conditions: one with two flashes, the first flash paired with a beep [2F1B], and the other with three flashes, the first two flashes paired with beeps [3F2B-r]. A final experiment asked participants to report the locations of the perceived flashes in the 3F2B condition when two flashes were perceived. Results: Expt. 1: Three flashes with no beeps [3F0B] and with three beeps [3F3B] were perceived as approximately three flashes, whereas three flashes accompanied by two beeps [3F2B] was perceived as two flashes; the number of perceived flashes in 3F2B is significantly fewer than with 3F3B (p = 10-34). Expt. 2: The number of perceived flashes was significantly greater when the beep-flash pairs preceded the lone flash [3F2B-r], rather than when flanking [3F2B] (p = 10-8). This indicates that the last flash-beep suppresses the perception of the middle lone flash postdictively in 3F2B trials. Expt. 3: The distribution of reported flash locations is consistent with suppression of the middle flash. Discussion: Our results indicate that auditory stimuli can change visual perception postdictively, thereby broadening postdictive phenomena to suppression. Together with the "illusory rabbit", results suggest that audition dominates vision under short time conditions.

43.4054 Audiovisual "Illusory Rabbit": The Role of Postdiction in Crossmodal Spatiotemporal Dynamics Shinsuke Shimojo[1](sshimojo@caltech.edu), Noelle Stiles[1], Monica Li[1], Carmel Levitan[2], Yukiyasu Kamitani[3]; [1]Biology and Biological Engineering, California Institute of Technology, [2]Psychology, Occidental College, [3]Graduate School of Informatics, Kyoto University

Background: The temporal paradox of stimuli following an event affecting that event's perception (postdiction), provides a unique window into brain processing (Shimojo, fpsyg 2014). This study revisits the audiovisual rabbit illusion (Kamitani & Shimojo, VSS 2001) and examines whether audition can modify visual perception postdictively. Methods: A sequence of flashes (13 ms each, total stimulus duration 145(?) ms) was presented on a computer monitor moving left-to-right, while accompanying beeps (7 ms each) were communicated on a single left-hand-side speaker. Stimuli included: two lone flashes (2F0B), two flash-beep pairs (2F2B) and two flashes and three beeps, with the two flashes accompanying the first and the third beeps, respectively (2F3B). Subjects reported the number of flashes perceived (Expt. 1), or both the number of flashes and the location of the flashes (Expt. 2). Results: Expt 1: Participants (N = 8) perceived significantly more flashes with 2F3B than 2F2B (p < 10-33), indicating the perception of an illusory flash in the 2F3B condition. Expt 2: The second flash (of three reported flashes) location in the 2F3B condition was midway between the first and third flash, indicating the illusory flash's location is postdictively determined. Discussion: The illusory flash following the first flash was perceived to be moved laterally in space toward the final flash location. This mid-location of the illusory flash must be determined after its perception, as no spatial movement is conveyed before or during its presentation. It indicates that the location of the illusory flash can be postdictively modified, and further that postdictive processing extends to crossmodal interactions.

Acknowledgement: CREST/JST

43.4055 Hierarchical Structure in Visual and Auditory Rhythms as Revealed by Cross-modal Synchrony Stephen Palmer[1](palmer@cogsci.berkeley.edu), Joshua Peterson[1]; [1]Psychology Department, University of California, Berkeley

The metrical hierarchy of musical rhythm is defined by the structure of emphasis on beats in measures. We investigated the perceived structure of 3/4, 4/4, and 6/8 time signatures in auditory and visual meter using cross-modal goodness-of-fit ratings for visual and auditory probes, respectively. In the auditory rhythm conditions, four measures in 3/4, 4/4, and 6/8 time were defined by a louder drumbeat followed a series of 2, 3, or 5 softer, equal-timed drumbeats, respectively. A visual probe circle was introduced into the next four measures at the same phase-angle relative to the auditory downbeat (0°/45°/60°/90°/120°/135°/180°/225°/240°/270°/300°/315°). In the visual rhythm conditions, context and probe modalities were reversed, with analogous visual rhythms being defined by brief presentations of a larger downbeat circle followed by a series of 2, 3, or 5 smaller circles. Auditory drumbeat probes were introduced into the next four measures at one of the same 12 phase-angles. In both cases, participants rated how well the probe stimulus "fit" the rhythmic context in the other modality. The probe's positional effect on fit-ratings revealed a beat-defined metric hierarchy (rather than a phase-angle-defined hierarchy) for both modalities, that was stronger and better-defined for auditory than visual rhythms. In 4/4 time, ratings decreased from down-beats (0°) to on-beats (180°) to off-beats (90°/270°) to semi-beats (45°/135°/225°/315°) to non-beats (60°/120°/240°/300°). In 3/4, they decreased similarly from down-beats (0°) to off-beats (120°/240°) to semi-beats (60°/180°/300°) to non-beats (45°/90°/135°/225°/270°/315°), but at different phase-angles. Further experiments show that these metric hierarchies can be influenced by different visual downbeat features (e.g., intensity, position, hue, and saturation), that cross-modal stimulation can influence the perceived downbeat, and that similar hierarchies are present even if the probed beat is absent in the cross-modal, contextual rhythm (e.g., loud/quiet/soft/soft in auditory 4/4 time, with the visual probe at the missing 2nd beat).

Acknowledgement: NSF Grants BCS-0745820 and BCS-1059088 Gift from Google

Spatial Vision: Neural mechanisms

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4056 Visualizing allocation of attention in naturalistic scenes: an fMRI p-imaging study of human early visual cortex Karl Zipser[1](karlzipser@berkeley.edu), Kendrick Kay[2], Amrita Puri[3]; [1]Helen Wills Neuroscience Institute, U.C. Berkeley, [2]Center for Magnetic Resonance Research, University of Minnesota, Twin Cities, [3]Department of Psychology, Illinois State University

How flexibly can visual attention modulate retinotopic cortical representations of complex scenes? To address this question, fMRI scanning of early visual cortex was conducted as three fixating subjects viewed naturalistic images. For each image, subjects were instructed to attend to distinct scene elements during separate presentations. As a control, subjects were instructed to read small and rapidly presented letters appearing at fixation under the same conditions. A technique called p-imaging was employed to project functional activity measurements onto the image space in order to visualize how the allocation of attention modulates BOLD signals. Relative to the reading control, allocation of attention to different scene elements yielded positive modulation of BOLD signals at corresponding locations in the p-images. The magnitude of this modulation was comparable to that which could be explained by low-level image features such as textures and edges. The shape and position of attentional modulation revealed in p-images closely corresponded to the spatial extent of the attended objects. Attention to a relatively small peripheral face or other object elicited focused modulation. In contrast, allocation of attention to specific locations in featureless background parts of scenes resulted in spatially diffuse positive modulation within these areas. When attention was differentially allocated to broad complementary scene regions -- figure vs. background in realistic scenes, or different figure-ground interpretations in ambiguous synthetic scenes -- differential modulation was sufficiently pronounced and widespread across the visual field so as to yield highly uncorrelated p-images. These results show that the different subjective experiences related to different ways of allocating attention correspond to highly specific patterns of BOLD signals in early visual cortex, and suggest that the potential for attentional modulation increases with the richness of scene content.

Acknowledgement: NSF grant IIS-1111765 to Bruno Olshausen

43.4057 **Response variability is shared between similarly tuned neural populations** Ruben van Bergen[1](r.vanbergen@donders.ru.nl), Janneke Jehee[1]; [1]Donders Institute for Brain, Cognition & Behavior, Radboud University, Nijmegen, The Netherlands

Cortical activity is highly variable across time, but the origin of this variability remains unclear. Increasing evidence suggests that not only local stochastic processes (i.e. noise) cause neural response variability; rather, a large share of cortical variability may arise due to more global cognitive processes, such as arousal or attention, affecting the responses of whole populations of neurons. We used functional MRI to investigate the nature and potential source of trial-by-trial activity fluctuations in human visual cortex. Participants viewed annular gratings in a range of orientations. The measured BOLD activation patterns varied from trial to trial, even when the orientation of the stimulus was held constant. To examine the structure of across-trial variability in cortical responses, we computed voxel-by-voxel correlation matrices from activity in areas V1, V2, and V3 combined. This revealed that voxels of similar orientation preference share more response variability than voxels with dissimilar tuning properties. The strength of this effect diminished with increasing Euclidean distance between pairs of voxels, but interestingly, remained significant up to distances of more than 5 cm. Crucially, spatial proximity alone was a poor predictor of shared response variability, ruling out explanations based on spatial smoothing artifacts of the imaging method (such as those due to the point spread function, or small movements by the participant). The global nature of these spontaneous fluctuations suggests long-range feature-tuned connections across retinotopic space.

43.4058 **Problems associated with a nonlinear relationship between neural and fMRI BOLD responses and a solution** Bosco Tjan[1](btjan@usc.edu), Pinglei Bao[2], Christopher Purington[1]; [1]Department of Psychology, University of Southern California, Los Angeles, CA, [2]Division of Biology and Biological Engineering, Caltech, Los Angeles, CA

Using the unique organization of an achiasmic individual's visual cortex, we showed that the amplitude of an evoked BOLD response is proportional to the amplitude of the evoked neural response raised to a power of approximately 0.5 (Bao, Purington & Tjan, 2015, eLife). Specifically, we found that in V1-V3 of an achiasmic individual, there are two nearly identical but non-interacting neural populations that are finely intermingled in the same cortical location. Their population receptive fields are spatially disjointed, allowing independent control of each population with visual stimuli. Since the neural populations do not interact, presenting two identical stimuli, each to one of the receptive fields, doubles the local neural activity relative to presenting just one. This in-vivo system lets us identify the nonlinearity between neural and BOLD responses independently from any nonlinearity between stimuli and neural responses. In the current study, we analyzed data from several experiments with the achiasmic participant and found that a simple linear-nonlinear model can approximate the neural-BOLD relationship in time. This model postulates a hemodynamic "control signal" that is linearly related to the evoked neural response during a stimulus event. The resulting BOLD time course is the sum of such control signals, raised to a power of 0.5 in a sign-preserving manner. This model suggests that nonlinearities associated with spatial summation, adaptation, and surround suppression observed with fMRI can be considerably contaminated by hemodynamic nonlinearity, an observation supported by recent findings (Bao et al., 2014VSS). The model also predicts that functional connectivity inferred from task states by linearly regressing out task-related activities can be misleading, since task harmonics produced by the nonlinear hemodynamics will be present in the residual. Squaring a baseline-subtracted BOLD response before applying any general linear model and using a modified hemodynamic response function can reduce the effects of hemodynamic nonlinearity on results.

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43.4059 **Decoding of visual stimulus location in the human hippocampus** Anna Shafer-Skelton[1](shafer-skelton.1@osu.edu), Julie Golomb[1]; [1]Department of Psychology, The Ohio State University

The hippocampus is an area well known for its role in memory and spatial navigation, and it has recently been implicated in visual perception. Surprisingly, there has been little research investigating how locations of visual stimuli are represented in the hippocampus. Here, we ask: 1) Does the hippocampus contain representations of stimulus location?, 2) What type of location does it represent?, and 3) Is location represented in the same areas of hippocampus as stimulus category? Using a blocked design, we presented participants with stimuli (objects or scenes) in a given location (left or right of fixation) while they maintained a given gaze position (left or right side of screen). We used fMRI MVPA to test whether hippocampus contained different types of information about visual stimuli, e.g. category information, "within-fixation location information" (for conditions that shared the same gaze position), and "across-fixation location information" (for conditions that differed in gaze position). In the right hippocampus, we could decode information about both the category and location of a stimulus. Notably, this location information was preserved across different gaze positions in retinotopic (gaze-centered) coordinates, with a similar magnitude to within-fixation location information. These results were similar to what has been found in higher-level visual cortex (Golomb & Kanwisher, 2012). We next performed searchlight analyses within hippocampus to examine the distribution of each type of information. We found a strong correlation between the searchlight outputs for within-fixation location information and across-fixation retinotopic information, suggesting that these two types of location information could share a similar neural representation. In contrast, neither type of location information was correlated with category information, and the location-location correlations were significantly stronger than the location-category correlations. This suggests that different parts of the hippocampus may be responsible for location vs. category information, which could have important implications for object-location binding.

Acknowledgement: NIH R01-EY025648 (JG), Alfred P. Sloan Foundation (JG)

43.4060 **fMRI Pattern Similarity Analysis Reveals Oblique Effects Throughout The Human Visual Cortex** Michael Pratte[1,2](prattems@gmail.com), Sam Ling[3], Frank Tong[1]; [1]Vanderbilt University, Psychology Department, [2]Mississippi State University, Psychology Department, [3]Boston University, Psychology Department

Many animals, including humans, are better at detecting and discriminating cardinal orientations (vertical and horizontal) than oblique orientations. Studies of non-human primates have suggested that the physiological loci of these so-called oblique effects are present in early visual areas. However, in studies of humans the neural signatures of the oblique effect have been elusive. Some recent fMRI studies have failed to find differences in mean BOLD responses to different orientations, while others have demonstrated a reverse oblique effect, finding that mean BOLD responses are greater for oblique than for cardinal orientations. Here, we present a novel, non-parametric approach to fMRI pattern analysis that allows us to measure the precision of feature representations in cortical activity patterns. Using this approach, we find robust oblique effects in activity patterns in early visual areas (V1-V3), with more sharply tuned pattern responses around cardinal orientations. This advantage in tuning precision for cardinal orientations corresponded well with behavioral discrimination thresholds, and was observed even when mean BOLD responses revealed a reverse oblique effect. Computational modeling of orientation-tuned cells suggests that behavioral discrimination thresholds, the oblique effect in pattern activity, and the reverse oblique effect in mean BOLD can be accounted for simultaneously. The results of these simulations rule out several potential explanations for the observed fMRI effects, such as differences in the gain or number of neurons across the orientation space, and support a recently proposed efficient encoding model in which neurons tuned to oblique orientations have wider tuning bandwidths than those tuned to cardinal orientations. These results help reconcile previous conflicting findings in fMRI, and support the notion that the neural locus of the oblique effect includes early visual cortex. Additionally, our study demonstrates how pattern similarity analysis provides a general, powerful approach for understanding neural representations of continuous feature spaces such as orientation.

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43.4061 **Orientation-Tuned Surround Suppression in the Human LGN** Sonia Poltoratski[1,2](sonia.poltoratski@vanderbilt.edu), Devin McCormack[1], Frank Tong[1,2]; [1]Vanderbilt University Department of Psychology, [2]Vanderbilt Vision Research Center

Surround suppression is a mechanism by which stimuli beyond a neuron's classical receptive field can modulate its response, and is critical for efficient natural vision. Studies have found suppression to be systematically dependent on the features of the surrounding stimulus, including its contrast, motion direction, and orientation; for instance, stimuli are most suppressed when the surround is iso-oriented, and least suppressed – or even enhanced – when the center and surround orientations are orthogonal. While surround suppression in the early visual system has typically been studied with single neuron recordings, more recent fMRI work has measured similar effects on a population level in early human visual cortex. Here, we report the first BOLD measures of surround suppression in the human lateral geniculate nucleus (LGN). We used high-resolution fMRI at 7 Tesla to investigate orientation-tuned surround suppression; our stimuli were large (4dva) annuli of sinusoidal gratings presented parafoveally. These center annuli were surrounded by a full-field grating that was either of the same or of an orthogonal orientation, while spatial phase was randomized. Surround suppression was defined as weaker responses at the center location when center/surround were iso-oriented than when their orientations were orthogonal. Across five observers, significant suppression was found in the LGN ($t(4) = 4.153$, $p = 0.0142$), as well as in cortical visual areas V1-V3. This stands in contrast with our prior findings that mean BOLD responses in the LGN are not modulated by orientation-defined salience when a particular grating and surrounding context are spatially separated (Poltoratski et al., VSS, 2015). Our results provide evidence of orientation-specific processing in the human LGN involving spatial interactions of surround suppression.

Acknowledgement: This research was supported by grants from the National Science Foundation (BCS-1228526) to FT and NSF-GRFP fellowship to SP, and was facilitated by an NIH P30-EY008126 center grant to the Vanderbilt Vision Research Center.

43.4062 **A deep convolutional energy model of V4 responses to natural movies** Michael Oliver[1](michaeloliver@berkeley.edu), Jack Gallant[1,2,3]; [1]Helen Wills Neuroscience Institute, University of California, Berkeley, [2]Program in Bioengineering, University of California, Berkeley, [3]Department of Psychology, University of California, Berkeley

Area V4 is an important intermediate stage of visual processing. However, it has been very difficult to characterize and model the tuning properties of V4 neurons. For example, no current models of V4 neurons can accurately predict responses to natural images. This is in stark contrast to models of V1 and MT, where responses can be predicted well. V4 neurons have large, nonlinear receptive fields, and this makes it difficult to estimate their tuning properties using conventional methods: modeling V4 amounts to solving a high-dimensional non-linear regression problem with limited data. To effectively attack this problem, we first sought to collect as much data as possible by chronically implanting electrode arrays in area V4 of two macaque monkeys. Neurons were recorded while the awake animals viewed clips of large, full color natural movies. The chronic recordings were stable enough that neurons could often be held for several days. This allowed us to collect responses to hundreds of thousands (up to over 1 million) distinct movie frames, for hundreds of different V4 neurons. We then used several different neural network architectures to fit the data obtained from each neuron. The training signals for each fit neural network were the stimulus movie and the response from one neuron. The most successful neural network architecture that we tested was one that reflected insights from the Adelson-Bergen energy model, the scattering transform and deep convolutional neural networks. We call this the deep convolutional energy model. This model is simple and interpretable, and it predicts V4 responses significantly better than previous models. Deep convolutional energy models fit to V4 neurons approach the prediction performance of the best current models of V1 and MT neurons. Interpretation of the fit models provides important insights about the representation of visual information in area V4.

43.4063 **A Generalized Tilt After-Effect** Ahamed Miflah Hussain Ismail[1](h.a.ahamedmiflah@qmul.ac.uk), Joshua Solomon[2], Miles Hansard[3], Isabelle Mareschal[1]; [1]Experimental Psychology, School of Biological and Chemical Sciences, Queen Mary University of London, [2]Centre for Applied Vision Research, City University London, [3]Centre for Intelligent Sensing, School of Electronic Engineering and Computer Science, Queen Mary University of London

The Tilt After-Effect (TAE) is maximal when the adaptor and test are presented in the same part of the visual field (Gibson, 1937) and contain the same spatial frequencies (Ware and Mitchell, 1974). These results implicate low-level, spatial frequency (SF) selective processes in the TAE, but they do not exclude the possibility that higher-level, global processes may also contribute to the TAE. To quantify that contribution, we presented adaptor and tests in different parts of the visual field. TAEs were measured using a two-alternative forced choice method that eliminates many forms of non-perceptual bias. Observers adapted to stimuli tilted ±15° of upright (for houses) or ±15° of vertical (for gratings). Two tests were presented on each trial and observers selected the test with the smallest apparent tilt. In Experiment 1 we tested adaptation to tilted images of houses (taken in the fronto-parallel plane at eye level) in conditions where the adaptor and tests were: (a) the same house, (b) different houses, or (c) differently filtered versions of the same house (separated by more than 2 octaves for spatial frequency). In Experiment 2 we examined TAEs for gratings when the adaptor and tests had either (d) identical or (e) different spatial frequencies (separated by 2 octaves). In all conditions the TAE was significant ($p < 0.05$) for most observers (a: 4/5, b: 4/5, c: 5/5, d: 8/8, e: 5/6). In all conditions the average TAE was approximately 1° (a: 1.01°, b: 1.18°, c: 1.49°, d: 1.27°, e: 1.19°). We conclude that a generalized mechanism can contribute to the TAE. It is relatively unselective for spatial frequency and does not require the adaptor and test to be presented in the same part of the visual field.

43.4064 **Analysis of individual and spatiotemporal variability in human cortical contrast response functions: further evaluation of separable high and low contrast processes** Russell Hamer[1,2,3](russhamer2@gmail.com), Givago Souza[4,5], Thiago Costa[2], David Peterzell[6], Ana Milioni[2], Bruno Gomes[4,5,7], Luiz Silveira[4,5,7], Dora Ventura[2]; [1]Psychology Department, Florida Atlantic University, Boca Raton, FL, USA, [2]Departamento de Psicologia Experimental, Instituto de Psicologia, São Paulo, Brazil, [3]Smith-Kettlewell Eye Research Institute, San Francisco, CA, USA, [4]Instituto de Ciências Biológicas, Universidade Federal do Pará, PA, Brazil, [5]Núcleo de Medicina Tropical, Universidade Federal do Pará, Pará, Brazil, [6]John F. Kennedy University, Pleasant Hill, CA, USA, [7]Universidade Ceuma, São Luís, Maranhão, Brazil

Visual evoked potential (VEP) contrast response functions (CRFs) frequently manifest two linear limbs on log-contrast axes, a shallow limb at low contrasts, transitioning into a steep limb at high contrasts, implying contribution of multiple mechanisms. These could reflect magnocellular (M) and parvocellular (P) dominated responses, respectively (Nakayama & Mackeben, 1982; Bobak et al., 1984; Tyler & Apkarian, 1985; Souza et al., 2007, 2008). Preliminary principal component analyses of individual differences in sweep VEPs (sVEP) supported this hypothesis (Hamer, Souza et al. 2013). To further elucidate the underlying mechanisms, we apply factor analysis to CRFs obtained with the efficient sweep VEP (sVEP) recorded from 9 subjects viewing 0.4, 2, 10 or 16 cycles/degree achromatic sinewave gratings (161 cd/m2 mean luminance), phase-reversing at 4.29, 6, 10 or 15 Hz. In each 10-sec sVEP trial, grating contrast increased logarithmically from 1.4 to 90%. A vector average Discrete Fourier Transform amplitude (without adaptive filtering, to prevent correlations across contrast) at the second harmonic was calculated for 10 contrast sweeps per spatiotemporal condition. We estimated underlying factors in log-transformed amplitudes (to normalize distributions), examining covariances, and rotated (Varimax) the principal components to approximate "simple structure" and maximize the number of zero or non-zero loadings. Our analysis revealed two factors that accounted for the 74.7% of the data's variance: Factor 1 (FC1) scores increased monotonically with contrast, loading more onto high contrasts. FC2 decreased with contrast, loading more onto low contrasts, the two crossing between 10-20% contrast. These results were similar to prior findings (Hamer et al., 2013; Peterzell, Bubl & Bach, 2015). FC1 (high-contrast) scores were higher at low temporal frequencies (TFs) across spatial (SFs). FC2 (low-contrast) scores were highest at 2 c/deg for all TFs. The results will be discussed in relation to potential M- and P-contributions to the sVEP.

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43.4065 **Temporal characteristics of luminance noise affect the pathway mediating contrast sensitivity** Cierra Hall[1,2](fearielfire@gmail.com), J. Jason McAnany[1,2]; [1]Ophthalmology and Visual Sciences, Medicine, University of Illinois at Chicago, [2]Bioengineering, Engineering, University of Illinois at Chicago

Purpose: To determine if the temporal characteristics of externally added luminance noise can be manipulated to target selectively the magnocellular (MC) and parvocellular (PC) visual pathways. Methods: Letter contrast sensitivity (CS) was measured for three visually-normal subjects using briefly presented letters. CS was measured for letters of different size under four paradigms: 1) against an unchanging luminance pedestal ("steady-pedestal paradigm," known to target the MC pathway),

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2) against a pulsed luminance pedestal ("pulsed-pedestal paradigm," known to target the PC pathway), 3) in a field of unchanging luminance checks (static noise), 4) in a field of randomly changing luminance checks (dynamic noise). CS was measured for letters that were high- and low-pass filtered with a range of filter cutoffs to quantify the object frequency information (cycles-per-letter) mediating letter identification, which was used as an index of the pathway mediating CS. A follow-up experiment determined the effect of target duration on the object frequencies mediating letter identification in static and dynamic noise. Results: Object frequency increased as letter size increased for each paradigm, consistent with previous results showing that subjects use different information to identify letters at different sizes. ANOVA indicated that the object frequencies measured under the static noise and steady-pedestal paradigms did not differ significantly ($p > 0.05$), but differed considerably from those measured under the dynamic noise (both $p < 0.05$) and pulsed-pedestal (both $p < 0.05$) paradigms. The object frequencies mediating letter identification were independent of target duration in static and dynamic noise. Conclusions: The spatiotemporal characteristics of noise can be manipulated to target the MC (static noise) and PC (dynamic noise) pathways. The ability to target these pathways at long stimulus durations in a letter identification task has potential importance in the design of future clinical CS tests.

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43.4066 **Prolonged exposure to image skews of dynamic natural scenes facilitates future adaptation performance** Selam Habtegiorgis[1](selam-wondimu.habtegiorgis@uni-tuebingen.de), Katharina Rifai[2], Siegfried Wahl[3]; [1]Institute for Ophthalmic Research, Eberhard Karls University, Tuebingen, Germany, [2]Institute for Ophthalmic Research, Eberhard Karls University, Tuebingen, Germany, [3]Institute for Ophthalmic Research, Eberhard Karls University, Tuebingen, Germany

Visual system plasticity stabilizes perception for disrupted vision, e.g. due to distortions accompanying artificial image magnifications (Adams, Banks, & van Ee, 2001; Meister & Fisher, 2008). Here, we demonstrate that the visual system recalibrates its response stimulus independently for image skews, which comprise magnifications in oblique directions, in dynamic natural scenes. Moreover, previous exposure to such distortions facilitates future fast recalibration performance of the visual system. This robust plasticity of visual system was inspected after alternate adaptations to two groups of natural image sequences, one skewed at +25° and the other at -25° in both horizontal and vertical directions. The perceived undistorted skew angle (PUA) of a subjective square checkerboard was used to quantify the aftereffect using the method of adjustment. First, PUA was measured with 23 participants after alternate adaptations to the oppositely skewed natural image sequences each lasting 15 minutes. The resulting PUAs shifted from the baseline in the direction of the adapting skew and were found to be significantly different from one another. After four weeks, PUA was measured after brief alternate exposure, 40 second, to the same distortions with 20 participants. Ten of them participated in the previous experiment (experienced) and the other ten never had prolonged exposure to these specific distortions (novice). Significantly different PUAs, shifted in the direction of the adapting skew, were observed only in the experienced subjects. Accordingly, long-term memory of the two skew distortions that affects future adaptation performance was revealed. Similar to the aspect ratio computation in cardinal axis (Regan and Hamstra, 1992), we hypothesize that special neural mechanisms might exist to compute dimensional asymmetry of orthogonal pairs in all directions and their recalibration performance might be facilitated by previous prolonged exposure of asymmetry in the specific directions.

43.4067 **Concordance of Resting-State vs Task-Based FMRI Maps of Human Visual Cortex** Edgar DeYoe[1](deyoe@mcw.edu), Ryan Raut[1], David Ritchie[1], Jed Mathis[1]; [1]Dept. Radiology, Medical College of Wisconsin

Resting-state FMRI (rsFMRI) requires minimal subject participation yet provides brain maps of vision- and other function-specific networks making it highly advantageous for clinical brain mapping. However, rsFMRI and conventional task-FMRI (taFMRI) may not reflect identical neural mechanisms. To compare rsFMRI and taFMRI maps of visual cortex on a voxel-by-voxel basis, three healthy individuals and 5 brain tumor patients underwent taFMRI vision mapping with an expanding checkered annulus extending to 20o eccentricity plus rsFMRI with eyes closed. TaFMRI data were subjected to both independent components analysis (ICA) and correlation analysis (COR) whereas rsFMRI data were processed with ICA. Activation patterns were compared across a wide range of statistical threshold settings. For each voxel, the presence (+) or absence (-) of rsFMRI and taFMRI activation was scored as one of 4 logical combinations (+/+,+/-,-/+,-/-). Brain maps of the voxel classifications revealed regions of high predictive validity (+/+ and -/-) versus zones of mismatch (+/- and -/+). Predictive validity was threshold dependent, but for each subject a single pair of taFMRI and rsfMRI thresholds was found that minimized this dependence and was unbiased. At such thresholds, the average predictive validity was 0.62 for taFMRI-COR vs rsfMRI-ICA, and 0.59 for taFMRI-ICA vs rsfMRI-ICA, similarly for both healthy subjects and tumor patients. Mismatches were non-random, often located at the edges of the fMRI patterns partly reflecting the more limited retinotopic extent of the taFMRI activation compared to rsFMRI. TaFMRI maps computed from the same dataset with ICA vs COR resulted in higher, but not perfect, predictive validity (0.75) suggesting that analysis method can be a significant source of variability. Conclusion: taFMRI and rsFMRI maps can be similar but the degree of concordance is threshold and analysis dependent. rsFMRI may provide more complete maps including regions not activated by taFMRI.

Acknowledgement: NIH R42NS081926, R42CA173976

43.4068 **A network of topographic numerosity maps in human occipital, parietal and frontal lobes** Ben Harvey[1,2](b.m.harvey@uu.nl), Serge Dumoulin[2]; [1]Faculty of Psychology and Education Sciences, University of Coimbra, Portugal, [2]Experimental Psychology, Helmholtz Institute, Utrecht University, Netherlands

We recently described neural populations tuned to object number (numerosity) forming a topographic map in the human right parietal lobe (Harvey et al, Science 2013; Harvey et al, PNAS 2015). Previous studies describe activations in many parietal and frontal areas during numerosity tasks. We hypothesize that there is an extended numerosity-processing network comprising multiple numerosity maps, analogous to the multiple visual field maps that process visual space. Methods: We acquired ultra high-field fMRI (7T) data while showing visual stimuli of changing numerosity. We used several stimulus conditions that distinguish numerosity selectivity from selectivity to co-varying low-level stimulus features. We analyzed responses using population receptive field modeling (Dumoulin and Wandell, 2008, Neuroimage) to summarize each recording site's response as a tuning function with a particular preferred numerosity and tuning width. Results: We find several maps of gradually changing numerosity. Our previously described map lies medial to the intraparietal sulcus and posterior to the postcentral sulcus. We find two further parietal numerosity maps in the postcentral sulcus, one superior and one inferior to the junction with the intraparietal sulcus. In the occipital lobe, we find one map at the superior end of the parieto-occipital sulcus, with another anterior/inferior to the lateral occipital sulcus and posterior/inferior to the inferior temporal sulcus. Finally, we find a frontal numerosity map at the junction of the pre-central and superior frontal sulci. Progressions of preferred numerosity and tuning width are remarkably similar between maps, although we find some differences in lateralization. Conclusion: Numerosity maps group similar numerosity preferences together, and gradually change numerosity preferences across the cortical surface. However, several broadly distributed areas process numerosity, each with similar response properties. We speculate these areas may support distinct cognitive roles of numerosity processing, such as multiple object tracking, distribution of attention across objects, and decision-making.

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Motion: Optic flow

Monday, May 16, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.4069 **Signatures of egocentric location and speed processing in early visual cortex** Elizabeth Chrastil[1,2](chrastil@bu.edu), Michael Hasselmo[1], Chantal Stern[1,2], Sam Ling[1]; [1]Psychological & Brain Sciences, Boston University, [2]Athinoula A. Martinos Center for Biomedical Imaging

Although early visual cortex is typically associated with low level visual processing, a variety of higher-level processes, such as attention and memory, have been shown to modulate visuocortical responses. Interestingly, recent animal studies have found that responses in visual cortex are also substantially modulated by locomotion. Here, we use fMRI to examine whether navigational location and speed influence the magnitude of BOLD responses in human visual cortex. To test this hypothesis, we scanned 24 participants while they viewed simulated self-motion in a virtual environment. Specifically, participants viewed first-person travel along a path that looped in a circle (~5-25 sec) in a landmark-free virtual environment (Chrastil et al., JNeurosci, 2015). The traveled loops varied from trial-to-trial; some trials were traveled faster than others, some were of greater radii, and some could close, overshoot, or undershoot the start ('home') location. Participants were asked to perform a location-tracking task, whereby they indicated at the end of each trial whether the loop they were travelling on ended at the loop's home location, or at a different location. The results demonstrated substantially elevated visuocortical responses when a participant was close to the home location, suggesting a task-driven, egocentric distance-dependent modulation of visuocortical responses. Furthermore, preliminary analyses suggest that the amplitude of early visuocortical responses increased monotonically as a function of the angular speed of motion. Taken together, our results suggest that human early visual cortex bears signatures of processing self-motion information, potentially increasing the signal-to-noise ratio for behaviorally relevant visual signals during spatial navigation.

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43.4070 Center bias in perceived heading from optic flow

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Judgments of heading direction from optic flow often show a bias toward the center of the display, but this has not been systematically investigated. We measured center bias in conditions with varied optic flow information, and tested the coordinate frame of the bias. Observers viewed 3.5s displays of simulated self-motion presented on a head-mounted-display, and indicated their perceived heading direction with a cursor. As a measure of center bias, we estimated the slope of the linear relationship between simulated and judged heading direction. Four simulated environments were tested: a textured ground plane with scattered posts, a textured ground plane alone, a cloud of fixed dots, and a cloud of randomly drifting dots. We also varied field of view (100°x64° vs. 66°x40°) and simulated observer speed (1 m/s vs. 4 m/s). We found that center bias varied systematically with the quality of optic flow information. Biases were larger for a ground plane alone than with scattered posts, and for a noisy dot cloud than a rigid dot cloud. Biases decreased with larger field of view and faster speed. To rule out response bias, we varied the distribution of simulated heading directions. Similar results were observed when heading directions were sampled from an M-shaped distribution, suggesting that biases are perceptual. To test the coordinate frame of the bias, we varied the orientation of the head relative to the body (±10°), and found that biases followed the direction of the head and display. Our results are consistent with the influence of a Bayesian prior that prefers heading directions aligned with the head or gaze. The effect of such a prior would depend on the reliability of optic flow information, as observed here. This model could be implemented with center-weighted templates, which have been proposed to account for other findings.

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43.4071 Biological Motion Perception Improves Heading Estimation For Self-Motion Through Crowds

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Finding one's way through a crowd of people is a computationally demanding task. To navigate through crowded environments the brain must segment motion signals generated by the one's own translational movement from those generated by other moving individuals or objects in the scene. Despite the complexity of this problem, humans are able to rapidly and accurately assess dynamic crowds during self-motion, allowing them to move about safely on a day-to-day basis. The purpose of the current series of experiments was to investigate how people estimate their direction of travel in crowds based on visual information alone. Observers were shown scenes in which movement was simulated through crowds of intact or spatially scrambled point light walkers that articulated in place. They were then asked to estimate their heading direction. We found that heading estimates were significantly more accurate when crowds were comprised of intact as opposed to scrambled point light walkers. In a second experiment individual translational components were added to the walkers in the crowd, and the degree of walker articulation was manipulated. Though the addition of walker translation increased heading errors, the finding that heading estimation was more accurate for intact walker crowds than scrambled crowds was replicated. Additionally, we showed that walker articulation produced a reduction in heading errors independently of walker type. Together the results from these experiments suggest that, during locomotion through crowds, the visual system may take advantage of biological motion information in order to reduce spurious motion in the visual scene. Importantly, our results also suggest that the improved heading accuracy observed in the presence of intact walker crowds as compared to scrambled crowds is largely driven by global form cues.

43.4072 Effects of global form information on heading perception in central vs. peripheral vision

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We previously found that observers optimally combine both global form and motion cues for heading perception. Here we examined how global form information affects heading perception in central vs. peripheral vision by using a radial Glass pattern composed of random dot pairs that contained a form-defined focus of expansion (FOE) and a radial flow field that contained a motion-defined FOE. Four display conditions were tested: (1) A static Glass pattern displayed either in central (15° in radius) or peripheral vision (the surrounding annulus, 15° in width) with the flow field displayed in central or peripheral vision correspondingly. The form FOE of the Glass pattern had 0o, ±5o, or ±10o offset from the motion FOE of the flow field. (2) An integrated Glass pattern composed of random-dot pairs in a 3D cloud displayed in central or peripheral vision with the flow field displayed in central or peripheral vision correspondingly. The random-dot pairs in the integrated Glass pattern were oriented toward one direction on the screen (the form FOE) to form a radial Glass pattern while moving in a different direction simulating forward self-motion (the motion FOE). The form FOE of the integrated Glass pattern was offset from the motion FOE of the flow field as before but its motion FOE was consistent with that of the flow field. Heading perception bias was largest when the integrated Glass pattern was in central vision followed when it was in peripheral vision. Although the global form information in the static Glass pattern could be easily separated from the flow field, it still biased heading perception with its effect again stronger in central than in peripheral vision. We conclude that global form information affects heading perception regardless of its retinal position though its effect is stronger in central than in peripheral vision.

43.4073 Introducing the Head-Mounted Rotating Drum

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The rotating drum is a classic apparatus used to study circular vection – the visually induced illusion of self-rotation in a stationary observer. The observer sits in a large cylinder that has an illuminated interior, consisting of black and white vertical stripes that occupy the entire visual field. The drum and hence the stripes can rotate and make the seated observer feel that s/he is rotating in the direction opposite to the motion of the stripes. Advances in head-mounted display (HMD) technology have allowed researchers to induce vection using HMDs. For the first time, our group has replicated the rotating drum in a virtual reality HMD environment. We manipulated the simulated speed of the rotating drum, and recorded participant vection perception. Vection was measured and recorded by having participants rotate a circular knob capable of spinning infinitely in clockwise and counter-clockwise directions, while viewing the moving stripe pattern within the HMD. Participants were instructed to monitor their sensation of rotary vection and turn the knob in the direction opposite to their perceived self-rotation. Knob rotation speeds and rotation times are recorded and used to indicate vection strength. Knob rotation methods have been used in previous research to measure vection, however ours is a unique alteration in that 1)the rotation of the knob does not control the visual display 2)participants turn the knob in the direction opposite to their perceived self-rotation. Our method is proving to be direct and informative for measuring circular vection. Data suggest that 1)the HMD is capable of inducing vection, similarly to the classic rotating drum apparatus 2)vection strength varies as a function of the simulated rotation speed of the visual display. This study further validates the use of HMDs for studying self-motion as it has allowed us to integrate a classically used apparatus within an HMD.

43.4074 Seeing the world as it is: veridical motion perception in schizophrenia and effects of non-invasive transcranial electric stimulation

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Monday AM

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We studied the causal involvement of area MT+ in an optic flow paradigm. Firstly, we explored the performance of 15 schizophrenic patients and age-matched controls in a task that assessed the local and global contributions to trajectory perception of a moving probe in an optic flow field. Schizophrenic patients showed a significantly reduced bias in trajectory perception for global motion processing only. Secondly we studied the effects of non-invasive transcranial electric stimulation (TES) over the MT+ region. We hypothesized that TES would interfere with processing in the MT+ by modulating spatial suppression of global motion signals. Participants indicated the direction of the moving probe in the global or local optic flow task, while receiving 20 minutes of anodal, cathodal, HF-RNS or sham TES stimulation at 1.5 mA over right MT+ region and right ATL region (control site). We found that cathodal and HF-RNS stimulation over MT+ region had opposite effects on trajectory perception in global optic flow condition. While HF-RNS stimulation reduced the bias of trajectory perception, cathodal stimulation increased it. In summary, we demonstrate the high specificity of brain stimulation over area MT+, since stimulation applied over the ATL, a brain area that is not involved in processing optic flow, was ineffective. Using HF-RNS stimulation over area MT+, we show that the behavioural pattern seen in patients with schizophrenia can be mirrored in neurologically intact participants. Specifically, we show that temporary interference with neural processing in area MT+ produces a selective impairment of global motion processing. In the future, the stimulation effects observed in this study could be combined with perceptual training paradigms to improve motion perception in patients with magnocellular deficits.

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43.4075 **Processing of visually simulated self-motion – an EEG-study** Constanze Schmitt[1](constanze.schmitt@physik.uni-marburg.de), Frank Bremmer[1]; [1]Dept. Neurophysics, Philipps-Universität Marburg, Germany

Everyday life requires monitoring of changes in the environment even without paying attention to it. Numerous EEG-studies have revealed that we are able to detect visual changes pre-attentively. Here we asked, whether also changes in visually simulated self-motion (heading) are processed automatically, i.e. without necessarily paying attention to it. We studied event-related potentials (ERPs) in a visual oddball paradigm. ERPs as observed in response to standard (80% occurrence) and deviant (20% occurrence) stimuli were compared in order to test for the occurrence of visual mismatch negativity (MMN). The MMN is a component of an event-related brain potential that reflects a pre-attentive mechanism for change detection. In this study the subject's attention was drawn off the self-motion stimuli by one of two different unrelated secondary tasks which they had to perform during stimulus presentation. Subjects viewed a random dot pattern that simulated self-motion across a ground plane. The self-motion stimuli (37° x 11°) were presented on a computer monitor in front of them. Standard and deviant trials lasted 400 ms each and differed only in their simulated heading direction (forward-left vs. forward-right). Each trial consisted of a stationary and a following self-motion phase (800 ms and 400 ms, respectively). EEG-data were aligned to the onset of the simulated self-motion. Analysis of the evoked ERPs revealed a MMN between 100 ms and 170 ms after self-motion onset. Topographic analysis of this difference revealed a typical N2-component topography across occipital and parietal areas, which was lateralized, i.e. contralateral with respect to the simulated heading direction. Occurrence of the MMN was not dependent on the specific secondary task. The occurrence of MMNs as observed in our study provides evidence for a pre-attentive processing of visually simulated self-motion direction.

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43.4076 **Dissociable processing of radial motion direction and focus of expansion in human cortical areas V3A and V5/MT+**
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Neuropsychological studies (Beardsley and Vaina, 2005) have shown that patients with damage to V5/MT+ are unable to identify the direction of radially moving stimuli, but maintain their ability to identify the focus of the expansion (FOE). This suggests that FOE position is signalled by neural activity outside V5/MT+ and another motion area, V3A, has been identified as a possible cortical locus for this analysis (Koyama et al., 2005). The purpose of this study was to investigate the roles played by V5/MT+ and V3A in the perception of radial motion stimuli. We tested the hypothesis that human V5/MT+ (or more specifically its anterior sub-division, TO-2) is important for the perception of the direction of radial motion, whilst V3A, is crucial for FOE analysis. To this end we used repetitive Transcranial Magnetic Stimulation (TMS) to transiently disrupt areas TO-2 and V3A whilst participants performed psychophysical tasks involving the detection of changes in direction and changes in the position of the FOE of radial motion stimuli. Locations of all cortical areas were identified in preliminary fMRI experiments and TMS was delivered to these experimental areas (TO-1, TO-2, V3A) as well as a control site (LO-1) in participants whilst they performed the tasks (n=6). The results showed that application of TMS to area V3A disrupts performance on the FOE task, but not the direction discrimination task, whilst TMS to TO-2 generates the reverse effects. This double dissociation demonstrates that for radial motion stimuli, area V3A is necessary for analysis of the FOE, but not direction discrimination, whilst TO-2 is responsible for processing radial directions, but not the FOE.

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43.4077 **Is optic flow sufficient for biphasic steering movements typified by lane-changing?** Xin Xu[1](xin.xu3@uqconnect.edu.au), Guy Wallis[1]; [1]Centre for Sensorimotor Performance, School of Human Movement and Nutrition Sciences, University of Queensland, Australia

It has been shown that when participants are asked to conduct a lane change without visual feedback, they almost completely miss the return phase, leading to a systematical heading error. Here we investigated whether participants could conduct lane changes correctly in the presence of optic flow, particularly whether the return phase can be activated by optic flow. Two basic types of optic flow were used in two experiments: (i) a cloud of random dots distributed in all three dimensions, and (ii) a textured ground plane. In experiment 1 participants were asked to change lanes in the presence of either persistent or dynamic (re-drawn every 100ms) dots. In experiment 2, participants were asked to change lanes in the presence of a persistent dots or a textured ground plane. Steering behavior was assessed on the basis of several criteria, including the match between an individual's performance in the presence of full visual feedback versus performance under each test condition. The results revealed that in the presence of optic flow, the return phase was proportionally larger than in darkness, but still significantly less than that required to return the car to its original heading (one goal of a successful lane change). It appears, therefore, that optic flow can trigger the second, return phase of a lane change maneuver, although it remains insufficient to complete the maneuver. Best performance was produced in the presence of a ground plane which provides additional information (e.g. locomotor flow lines), suggesting that in a biphasic lane change manoeuver, participants were better able to utilize such information than the information perceived from a 3D cloud of dots, presumably instantaneous heading.

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Attention: Spatial selection and modulation 1

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4078 **The Spatial Borders of Search Resumption** Nir Shalev[1](nir.shalev@wolfson.ox.ac.uk), Nele Demeyere[1], Glyn Humphreys[1]; [1]University of Oxford

The attentional system allows individuals to bias and enhance the processing of a pre-defined target in the visual field. This capability can be demonstrated using visual search, where a single target is identified within a varying number of distractors, which can share features with targets. When the process of visual search is interrupted by temporarily eliminating all stimuli, participants can resume search when the visual array reappears. This rapid resumption of search is manifested in a shorter reaction time for a recurring search array. This phenomenon has been observed under many conditions, and traditionally explained in terms of visual prediction: with insufficient evidence for a target discrimination, the cognitive system relies on its limited information to direct attention towards where it hypothesizes the target will reappear. In the present study, we assessed how resumption is influenced by spatial shifts in attention. Participants were requested to identify a target in a search array which appeared for 100ms and disappeared for 900ms, repeatedly until response. Between the reappearances we shifted the locations of the whole array. We demonstrate how resumption persists when the array expands over a lager space before shrinking back

(Exp-1), and when the array shifts up and down in 5˚ visual angles (Exp-2). Finally, we manipulated the spatial shift systematically (10˚/20˚/30˚ visual angles) and found that resumption is eliminated only at the largest shifting distance (Exp-3). We discuss a theoretical account of the tradeoff between spatial shifts of attention and the maintenance of memory representations.

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43.4079 **Investigating the persistence of location probability learning in different reference frames** Douglas Addleman[1](addle005@umn.edu), Yuhong Jiang[1]; [1]Department of Psychology, University of Minnesota, Twin Cities

Recent studies show that visual search tasks in which targets occur more frequently in certain spatial regions result in improved task accuracy for more probable locations. This advantage emerges rapidly and extinguishes slowly when the target's location distribution becomes random. Here, we investigate the reference frame in which the frequently attended target locations are encoded. We changed the fixation position or the location of search items relative to fixation after participants learned to prioritize a high-probability location. Two hypotheses might explain how learning transfers: (1) spatiotopically, where the same screen location relative to the other items [DA1] is preferred regardless of fixation, or (2) retinotopically, where the same location relative to fixation is preferred. Our participants viewed four items in a diamond configuration, identifying the color of a target T among 3 distractor Ls presented briefly (160ms). Training locations were in one visual quadrant (e.g., the upper-left). One of the four locations contained the target more frequently (50%) than any of the other locations (17%). Participants in an initial experiment developed an accuracy advantage for the high-probability location in training that persisted through 10 blocks of testing in which the target was distributed equally between the four locations. In Experiment 2, the fixation point shifted after training to the center of the diamond configuration. In Experiment 3, the fixation point remained in the center of the screen during testing, but the diamond configuration was shifted to center around the fixation point. We examined whether the learned attentional preference remained in the same screen location or the same retinal location as the previously high-probability target location. Results showed no persistence in either the spatiotopic or retinotopic location. The alignment of spatiotopic and retinotopic reference frames may be important for the persistence of learned attentional biases.

Acknowledgement: NIH

43.4080 **Spatial Probability Improves Detection, Orientation Probability Improves Precision: Modelling as Neural Gain versus Tuning** Syaheed Jabar[1](syaheed.jabar@uwaterloo.ca), Britt Anderson[1,2]; [1]Department of Psychology, University of Waterloo, [2]Centre for Theoretical Neuroscience, University of Waterloo

Frequent targets are detected faster, probable locations searched earlier, and likely orientations estimated more precisely. As attentional manipulations often convey probabilistic cues about where or what stimuli are likely to appear, is it the case that probability effects and attentional effects are largely one and the same? If true, probability effects for space and features should be distinct as they are for attentional cues, e.g. spatial attention has been linked to changes in neuronal gain, while feature-based attention is thought to affect neuronal tuning. To examine dissociations in spatial versus featural probability, we had participants report both location and orientation of gratings, while location or tilt probabilities were independently manipulated. While orientation probability affected the precision of orientation reports, spatial probability only modulated the likelihood of stimulus detection. Our results demonstrate that even when no physical attentional cues are present, acquired probabilistic information on space versus orientation leads to separable 'attention-like' effects on behavior. These behavioral results are consistent with current theories of attentional effects at the neuronal level. We used population vector coding to implement spatial probability as an orientation agnostic increase in the gain of orientation responsive neurons and orientation probability as a change in orientation selective tuning. The result is that total neural signal is boosted for probable locations, but that the perceptual systems' sensitivity to orientations is not affected, consistent with the behavioral finding that spatial probability only affects detection and not precision. By contrast, having orientation probability affected tuning results in orientation sensitivity and interacted with innate perceptual biases that can also be modeled as tuning differences. Together these results support the claim that many attentional effects can be more directly explained as probability effects, and that the mechanism of probability effects are implemented by adjustments in the gain and tuning of selectively responsive neurons.

Acknowledgement: NSERC

43.4081 **Predictive cues narrow the window of spatial attention in crowded visual displays: Evidence from ERPs** Joel Robitaille[1](jrobitaille089@gmail.com), Rachel Vonk[1], Holly Lockhart[1], Stephen Emrich[1]; [1]Psychology department, Brock University

Our limited capacity for processing and filtering relevant information often results in binding errors when a target is presented in a crowded display. It was recently suggested that substitution of features between target and distractors might be the consequence of a failure to individuate the target during processing and that the N2pc event-related potential component is a reliable index of this phenomenon. Another theory, however, suggests that active competition between items during processing can account for these substitution errors. In this study, we introduced spatial cues to attempt to alleviate the active competition between items. Participants were presented with peripheral displays of far or near flankers that were either cued or uncued, and they were instructed to report the orientation of a radial line target among diametrical distractors. In the first experiment, the spatial cue was introduced before the visual display, while the second experiment presented a retro-cue. Behavioural results indicate that the guess rate is significantly reduced when targets are preceded by a predictive spatial cue compared to when retro-cues or neutral cues are present. Both experiments also produced an early positive contralateral component (P2pc) that was significantly reduced by the presence of pre-cues only. These results suggest that predictive spatial pre-cues may allow for a downscaling of the window of attention, which is reflected by the early lateralized P2 component, and facilitates the processing of information within a more restricted area. Modulating this window of attention helps resolve competition/individuation, as reflected by the decreased guess rate. In sum, the P2pc effect appears to reflect the biasing of spatial attentional during encoding.

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43.4082 **Brief visual events look briefer at locations suffering inhibition of return** Takayuki Osugi[1,3](tosugi@fechner.c.u-tokyo.ac.jp), Yuji Takeda[2], Ikuya Murakami[1]; [1]Department of Psychology, the University of Tokyo, [2]Automotive Human Factors Research Center,National Institute of Advanced Industrial Science and Technology, [3]Japan Society for the Promotion of Science

We investigated the influence of attentional inhibition on the perceived duration of a brief visual event. Although attentional capture by an exogenous cue is known to prolong the perceived duration of such an event, it remains unclear whether the attentional inhibition by an exogenous cue (i.e., inhibition of return: IOR) affects temporal perception. To this end, a spatial cuing task and duration judgment were combined. Each trial started with presentation of three horizontally aligned box-shaped stimuli, one of which was then suddenly flashed to serve as a peripheral cue. After one second, a filled square (target) was presented inside the left or right box. The target appeared in the cued side in a third of trials (cued condition), and in the opposite side in another third of trials (uncued condition). In the remaining trials, the cue appeared at the central box and the target appeared at either the left or right box (neutral condition). We measured the perceived duration of the target under these conditions using a matching method and recorded reaction times for target onset as is done in a typical spatial cuing paradigm. The results indicated that the target presented at the cued location was perceived to last shorter than that presented at the uncued location. Furthermore, the reaction time for the cued target was longer than that for the uncued target. Therefore, attentional inhibition induced by an exogenous cue contracted the perceived duration of a brief visual event at the inhibited location. In the pacemaker-accumulator framework, this shortened perceived duration can be explained by an increased miss rate of temporal-unit accumulation or by slowing down of the clock.

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43.4083 **Combining attention networks increases visual awareness** Mathieu Landry[1,2](mathieu.landry2@mail.mcgill.ca), Joshua Laxer[3], Amir Raz[2,4]; [1]Montreal Neurological Institute, McGill University, [2]Lady Davis Institute, Jewish General Hospital, [3]Department of Physiology, McGill University, [4]Department of Psychiatry, McGill University

The relationship between attention and consciousness thrives on complex and multifaceted interactions. While multiple studies support the idea that conscious perception requires attention, several reports highlight orthogonal dimensions, disentangling attention and consciousness. Here we aimed to show whether the combined effect of different attention systems improved perceptual access to sensory events and boosted conscious perception. We combined a double cueing task that concurrently engages goal-driven and stimulus-driven attention with a masking paradigm, wherein we varied target-mask latencies. Our results confirm that both cues reliably engaged each attention system. Moreover, the combined effect of goal-driven and stimulus-driven attention further contributed to visual awareness. This perceptual addition was apparent at low target-mask intervals where the isolated effects of each attention system scantily influenced conscious perception; the joint effect heightened consciousness. In line with recent findings suggesting that complex behaviors rely on coordinated interactions between multiple attention networks, our findings intimate that rather than interacting with conscious perception at a single level, attention likely integrates across multiple control systems to hone in on the conscious mind.

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43.4084 How do Endogenous Attention, Exogenous Attention and Metacontrast Masking Operate in Controlling Stimulus Visibility?

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Endogenous attention, exogenous attention, and visual masking are processes that control the visibility of a stimulus and determine whether it will register into consciousness and have access to short-term memory. Do these processes operate independently or interact as they control these common perceptual and cognitive outcomes? While earlier studies provided evidence for interactions between attention and masking, recent studies on common-onset masking reported that the interactions were artifacts of ceiling/floor effects. Our review of previous studies reporting metacontrast-attention interactions revealed similar artifacts. Therefore, we investigated in separate experiments whether exogenous attention and endogenous attention interact with metacontrast by using an experimental paradigm in which ceiling/floor effects are avoided. Observers fixated at the center of the display and reported the orientation of a target bar. An array of six or four oriented target bars followed by surrounding mask rings (with varying stimulus-onset-asynchronies) were presented around a virtual circle. The focus of attention was controlled by spatial cues with varying cue-target onset times. The endogenous cue (100% validity) consisted of an arrow at the center of the display that pointed to a randomly selected target bar. The exogenous cue (uninformative cue) was a small square flashed in the vicinity of a randomly selected bar. We also measured performance without masks (baseline). Critically, the target-mask luminances were adjusted individually to avoid saturation artifacts. Response errors were defined as the difference between the actual and reported orientations. We analyzed two different aspects of performance: The mean absolute response-errors, and the statistical distribution of signed response-errors. Our results show that both endogenous and exogenous attention modulate responses without interacting with masking, suggesting that they operate independently. Statistical modeling of the distribution of signed response-errors suggests weak interactions in modulating the probability of “guessing” behavior for some observers in both types of attention.

43.4085 Sequence effects of symbolic cueing by gaze and arrow cues

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Symbolic cueing paradigm has been widely used to investigate the attention orienting induced by centrally-presented gaze or arrow cues. Previous studies have found a sequence effect in this paradigm when arrows are used as central cues and simple detection tasks are included. The sequence effect has been explained as either the automatic memory retrieval of previous trial types or the strategy adjustment of participants depending on whether the previous cue correctly or wrongly shifts their attention. The present study investigated the universality of the sequence effect with different cues and different tasks. In experiment 1, sequence effects were tested with a central uninformative gaze cue and a discrimination task. The use of discrimination task would result in alternated/repeated target identities and response keys between consecutive trials. Experiment 2 was aimed to compare the sequence effects induced by gaze and arrow cues. Specifically, uninformative gaze and arrow cues were randomly mixed during the experimental trials to form four kinds of cue sequence conditions between consecutive trials: gaze-gaze sequence, gaze-arrow sequence, arrow-gaze sequence, and arrow-arrow sequence. It was found that sequence effects can be induced by central gaze cues and are not influenced by the repetition and switch of target identities (along with response keys). In addition, the sequence effect can even generalize across different cue types (from gaze to arrow, or from arrow to gaze). The results suggest that sequential processing is a common mechanism in attention orienting systems, and support the automatic retrieval hypothesis more than the strategy adjustment account.

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43.4086 Segregation and integration processes in inhibition of return

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Efficiently searching for a target in complex environments is a fundamental skill of the human cognitive system. One of the highly possible mechanism ensuring efficient visual search is inhibition of return (IOR). It refers to slower response to targets at previously cued locations than uncued locations and has been considered to facilitate foraging behavior by preventing attention from returning to previously inspected locations (Klein 2000). While traditional theories attribute IOR to a deficit in attention at the previously attended locations, a more recent theory proposed by Lupiáñez and colleagues (2001, 2007) suggested that IOR results from a competition process between integration of the target into an object representation created by the cue onset at cued locations (integration) and creation of a new representation at uncued locations (segregation). The integration vs. segregation theory (IS) has been demonstrated to be more robust than traditional theories in interpreting the effect of IOR under wide variety of experiment situations. However, there is few neuroimaging evidence for the IS theory. Here we aimed to seek for the neuroimaging evidence for the IS theory by using fMRI technique with an optimized stimuli sequence. fMRI data were acquired while the participants performed a cue-target task. The results revealed distinct activity patterns for the cued vs. the uncued condition. While the orbitofrontal cortex and the parahippocampal gyrus expressed smaller activity under the cued than the uncued condition, the frontal eye field and supplement eye field area expressed a reversed pattern of activity. Given the former areas is usually involved in encoding new information and the later areas is believed to be correlated with orienting of attention, the current results provided, for all we know, the first neuroimaging evidence for the IS theory.

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43.4087 Does the size of the attentional window influence encoding of hierarchical stimuli?

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How does the focus of attention influence the encoding of information? Research has shown that size and allocation of the attentional window has an influence on what information is attended to or missed. The size-scale of features effects processing of visual information. Previous research involving hierarchical stimuli (i.e. Navon letters) suggests precedence for global features. In the present experiment, we investigated the influence of attentional window size on accuracy of encoding hierarchical stimuli at the global and local level. Here we introduce a new method for manipulating the size of the attentional window and for collecting unconstrained responses. At the start of each trial, observers tracked a dashed-line rectangular box, which either broadened or narrowed in size after onset. This sequence was immediately followed by a brief presentation of two hierarchical letters presented simultaneously on the left and right sides of the screen (150 ms). The box preceding the hierarchical letters either broadened to a size large enough to include both letters at the global level, or narrowed to a size small enough to include a maximum of two letters at the local level at either side of the screen. Observers reported all letters they were able to identify. Results indicate an overall precedence of global letters. However, a narrow attentional window reduced global precedence, as would be expected with more focused attention. The narrow windows also produced more same-side identifications of both global and local letters. Additional analyses will examine dependencies between global and local perception.

43.4088 The emergence of the costs and benefits of grouping during visual search
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Previous visual search studies suggest that an attentional template for the target can be prioritized, but the breadth and nature of this attentional template has not been clarified. Grouping features into objects and objects into categories should facilitate search performance by maximizing the amount of information carried by the attentional template. A series of six N2pc ERP studies shows the emergence of the benefits and costs of grouping during visual search. Study 1 confirms that searching for 1 item (a letter) is more efficient than 2+ items (multiple letters) at both neural (attenuated N2pc) and behavioral levels (slower reaction time and lower accuracy). Regarding the benefits of grouping, Study 2 shows that if category knowledge can be applied during visual search, 1-item (a letter) and multiple-item search (any letter) is very similar. Study 3 extends this finding to real-world objects (clothing/faces). Using novel stimuli, Study 4 shows that a heterogeneous set of items grouped by an abstract rule and not by common perceptual features can facilitate search. Regarding the costs of grouping, when asked to search for one item in a category (search for the letter "A") and a foil item from the category appears (the letter "R"), participants exhibit attentional capture to the foil at both neural and behavioral levels (Study 2). Study 5 shows that the "foil effect" is predicted by prior experience (distinguishing healthy and unhealthy foods based on dieting intensity). Study 6 shows that the foil effect emerges over one experimental session via training with novel stimuli. Taken together, these six studies show how the emergence of categorically-based attentional templates can help overcome efficiency limitations in visual search by constraining the scope of target search due to previous knowledge, yet at the cost of false alarms to non-targets that fall within the search category.

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43.4089 Examining attention allocation during a proceduralized visual task
Theodros Haile[1](Theodros.haile001@umb.edu), Mahalakshimi Ramamurthy[1], Erik Blaser[1]; [1]Department of Psychology, University of Massachusetts Boston

Introduction. Conventionally, attentional selection is conceived as an interplay of willful, top-down choices and stimulus-driven, bottom-up demands. We hypothesized a third mode based on learned, context-dependent heuristics; a procedural selection - akin to that which governs skilled motor behavior - that occurs without cognitive supervision, but is still flexible and dynamic. This study contrasted how eye movement patterns in well-practiced versus un-practiced, but formally identical tasks (here, reading text forward versus backwards, respectively), were affected by distraction: when top-down selection is defeated, will the eyes still get to where they need to go? Methods. Four conditions were run blocked: Forward versus Backward reading (from bottom right to top left corner) each with and without a concurrent 1-back auditory tone-matching task (i.e. Dual- versus Single-task). A Tobii eye-tracker monitored reading; in the 1-back task, observers reported matches with a keypress. Nine observers saw six 250-word passages (excerpts from Kant) for each condition; tones were presented over headphones. Results. Our analyses focused on average fixation duration: forward, single-task: 270.2ms (SE 13.4ms); forward, dual-task: 292.8ms (SE 15.0), backward, single-task: 313.6ms (SE 10.5); and backward, dual-task: 361.1ms (SE 17.2). Reading backward or with a concurrent task lengthens fixation duration, but most importantly, the interaction - with the concurrent task disproportionately impairing unpracticed, backwards (as opposed to familiar, forwards) reading, was significant (a paired t-test of dual-task costs, for forward versus backward reading: mean difference: 24.85ms; SE: 6.74; t=3.686; p=0.0062). Performance in the 1-back task was 93% (SE 1.8) and 86% correct (SE 1.7) for forward and backward reading, respectively. Conclusions. We hypothesized that attentional selection during reading has been proceduralized, so puts diminished demands on top-down selection (cf. mind-wandering while reading) while unfamiliar backwards reading requires greater supervision, making it more susceptible to distraction. Our findings support this, suggesting the action of proceduralized attention.

43.4090 Involuntary attention in the absence of visual awareness
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The relationship between attention and awareness has intrigued scientists for decades. It is suggested that attention and awareness are two dissociated processes (Koch & Tsuchiya, 2007), based on considerations of previous research on voluntary spatial attention. However, such dissociation could be explained by the fact that participants were instructed to attend to the stimulus location denoted by visible markers (Bahrami et al., 2008), and it is known that voluntary spatial attention can affect neural processing in the absence of visual stimuli (Kastner et al., 1999). In addition, people usually do not voluntarily allocate their attention to an object outside awareness under ecological situations. To further elucidate the relationship between attention and awareness, we investigated involuntary attention under both aware and unaware conditions. In the first two experiments, we presented a brief cue with masks such that participants were unaware of the cue. This was followed by a search array, for which participants performed a shape singleton detection task. Although the cue was task-irrelevant and unconscious, we observed faster reaction times when either the cue's location or color was congruent with target. Thus unconscious stimuli can elicit both space- and feature-based attention. In addition, contrary to typical exogenous cueing paradigm, both feature- and space-based cueing effects were detected with a relatively long inter-stimulus-interval (ISI; 500ms) but not with a short ISI (200ms). In a further control experiment, we made the cue visible under both short and long ISIs. Here we found feature and spatial cueing effect only for the long ISI. This suggests that the visual noise from the masks delayed the processing of the cue under both aware and unaware conditions. Overall, our results provide further evidence for the dissociation between attention and awareness.

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43.4091 Evaluating Spatial-Based Attention Exclusivity for Hemifield Independence: Accounting for Effects of Salience, Distractor Preview, and Spatial Certainty
Joanna Lewis[1](joanna.lewis@knights.ucf.edu), Mark Neider[1]; [1]University of Central Florida

Previous research by Alvarez and colleagues (2012) found evidence of hemifield independence for spatial, but not feature-based attention in visual search. However, reaction times for feature-based searches in this study were faster than spatial-based searches, suggesting that participants may have perceived a reduced set size in the feature-based condition, masking possible hemifield effects. In three studies we further investigated the extent to which the hemifield advantage is limited to spatial-based search by evaluating the processing of distractors outside the feature and spatial subset of search items (Exp1), characterizing search array preview effects for both feature and spatial–based search (Exp2), and manipulating spatial certainty of the feature-based search task (Exp3). In all studies, participants searched for a rotated target "T" among distractor "L"s arranged unilaterally or bilaterally in black and white at several eccentricities. Feature-based search participants were told to look only within white search items; spatial-based participants were told to look only in the middle eccentricity. In Exp1 we found that including a target item at an unattended array eccentricity had no effect on search performance for both search conditions. Interestingly, we also found evidence of hemifield independence for both search conditions. In Exp2, RTs for feature-based search were faster, regardless of whether there was a preview; hemifield advantages were only observed for spatial-based search. In Exp3 we controlled for the spatial certainty of the target in both search conditions and found neither faster RTs for feature-based search compared to spatial-based search, or a feature-based hemifield advantage, suggesting that our observation of a hemifield benefit for feature-based search in Exp1 was likely attributable to spatial certainty of where the feature-based target occurred (always in the middle eccentricity). Evidence of hemifield independence persisted for spatial-based search. These results further support the claim that hemifield independence exists exclusively for spatial-based attention.

Acknowledgement: NSF

43.4092 A viewing time account for robust spatial cueing effects in all attentional paradigms
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Both predictive spatial cues and leptokurtic reward distributions may lead to increased response precision. Is this because of changes in the efficiency with which sensory information is evaluated at prioritized locations? Such an account would be consistent with attentional theories that emphasize noise exclusion and reductions in sensory uncertainty. To distinguish cue and reward effects on perceptual efficiencies from other attentional effects

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we devised a gaze contingent paradigm where we could equate stimulus viewing time across cue and reward conditions. We had participants report the orientation of Gabors presented in the periphery at contrasts too low for orientation to be reliably reported without fixation. Participants were instructed to look at the Gabor as quickly as possible and then report its orientation. By tracking a participant's gaze, we were able to limit Gabor fixation time to a standard 60ms across cue and reward conditions. Spatial cues appeared on 80% of trials and predicted the location of the Gabor with 50% validity. Reward conditions were either leptokurtic (peaked) for a block of 250 trials followed by a platykurtic (flat) reward block or a platykurtic block followed by a leptokurtic reward block. For one third of participants they began with a no reward condition followed by leptokurtic rewards. With a fixed viewing time there was no effect of any cue or reward condition on response precision. However, fixation response times were consistently faster for validly cued trials and pupil diameter was greatest for leptokurtic rewards. Thus, we conclude that the robust spatial cueing effects seen in essentially all attentional paradigms reflect additional viewing time that succeeds a valid cue when the stimulus is presented for a fixed duration or the viewing time is terminated by the participant's response.

Acknowledgement: NSERC

43.4094 **Time-resolved fMRI tracks attention through the visual field** Paige Scalf[1](paige.scalf@durham.ac.uk), Elexa St. John-Saaltink[2], Markus Barth[2], Hakwan Lau[3], Floris De Lange[2]; [1]Department of Psychology, College of Science, Durham University, [2]Ctr. for Cognitive Neuroimaging, Donders Institute for Cognitive Neuroscience, Radboud University, [3]Department of Psychology, University of California, Los Angeles

When multiple items must be monitored, does top-down attention act on their extrastriate representations in a parallel manner or in a serial manner? Synchronous neural activity during visual search by monkeys suggests that potential target items are enhanced in parallel (Bichot et al., 2005). Rhythmic presentation of spatially disjoint targets at optimal frequencies improves their detection by humans, however, suggesting that covert attention may in fact be rapidly cycled among attended locations (e.g Van Rullen et al., 2007). Here, we use highly time-resolved fMRI (TR =~90ms ms) to directly investigate the relative time at which top-down attention modulates individual extrastriate representations. In experiment one, we measured extrastriate signal evoked by stimuli in the four quadrants under three conditions. A simultaneous, 400 ms, 25% increase in luminance of all four items served as a model for simultaneously distributed attention. A sequential 100 ms, 100% increase in luminance for each item served as a model for sequentially allocated attention. We compared these with an attended condition, in which participants monitored the four items (whose luminance did not change). The onset and peak of the evoked BOLD response in corresponding extrastriate regions did not change significantly for simultaneous stimulation conditions ($p > .3$). Repeated-measures ANOVA revealed the difference between peak and onsets were significantly greater for the sequential ($p < .04$) and attended ($p < .05$) than for the simultaneous presentation condition. In a second experiment, reversing the order of sequential stimulation also reversed the order in which BOLD signal onset and peaked in visual cortex ($p < .05$). These data show that highly time-resolved fMRI can reveal difference in the time-course of signal across brain regions. Top-down attention acts across multiple extrastriate representations in serial.

Faces Perception: Experience, learning, and expertise

Monday, May 16, 8:30 am - 12:30 pm
Poster Session, Pavilion

43.4095 **Exploring Brain Mechanisms Underlying Individual Differences in the Effect of Acquired Familiarity on Face Learning and Generalization** Peter Cheng[1,3,4](kuanhao@gmail.com), Varden Hung[2,3,4], Emily Lin[2,3,4], Gary Shyi[1,2,3,4], S.-T. Huang[1,2,3,4]; [1]PhD Program in Cognitive Sciences, National Chung Cheng University, Chiayi, Taiwan, [2]Department of Psychology, National Chung Cheng University, Chiayi, Taiwan, [3]Center for Research in Cognitive Sciences, National Chung Cheng University, Chiayi, Taiwan, [4]Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University, Chiayi, Taiwan

To transform frequently encountered unfamiliar faces into familiar ones is one of the most important social skills. Shyi & He (2011, CJP) recently demonstrated that multiple exposures with modest level of expression variation can jointly influence face learning and generalization. Here, using fMRI, we examined neural mechanisms that may underlie the effect of acquired familiarity of faces. Twenty-seven participants (19 female) performed a personality rating task to familiarize themselves with novel faces outside the scanner, where each face was repeatedly presented 20 times with expression variation. A face/person recognition test was then administered during the functional scan, and participants had to decide whether the test face belonged to someone they learned during the rating task. Faces of old target, new target, and distractors were shown, where old target refers a face image that was previously presented, new target refers to a face wearing an expression different from when it was originally presented, and the distractor faces were those never shown before. After the recognition task, participants performed a one-back task, while viewing either static images or dynamic videos for localizing the bilateral face-selective ROIs, including OFA, FFA, STS and inferior frontal gyrus (IFG). Participants were divided into two groups according to their generalization performance. Those who exhibited relatively strong generalization, in comparison to those exhibited relatively weak generalization, yielded greater activations in the left OFA, left FFA, right mSTS, right pSTS, and right IFG areas. Moreover, the correlations between the BOLD signal change of face-selective regions and face generalization indicated that neural activations in the left FFA, right mSTS, bilateral pSTS, and right IFG can predict the magnitude of generalization to new target faces. Taken together, these results highlight the neural mechanisms that may underlie individual differences in the effect of acquired familiarity on face learning and generalization.

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43.4096 **The reverse caricature effect for faces caricatured in shape or texture** Marlena Itz[1](marlena.itz@uni-jena.de), Stefan Schweinberger[1], Jürgen Kaufmann[1]; [1]Department of General Psychology and Cognitive Neuroscience, Friedrich Schiller University of Jena, Germany

Recent evidence shows performance benefits and modulation of face-sensitive event-related potentials (ERPs) for learning and subsequent recognition of faces caricatured in shape or texture (Itz et al., 2014), but there is little evidence on whether this caricature learning advantage generalizes to recognition of veridical faces. Here we investigated whether learning faces as photorealistic caricatures improves subsequent recognition of their veridical counterparts compared to when faces had been learned as veridicals, the so-called reverse caricature effect (Deffenbacher et al., 2000). Facial images derived from a 3D camera system were caricatured selectively in either shape or texture by 50%. Participants learned faces across different viewing angles either as veridicals, shape caricatures, or texture caricatures. At test, all faces (learned and novel) were presented as previously unseen frontal veridical images. Participants performed a speeded old/new task, and we assessed accuracies, reaction times, as well as face-sensitive ERPs. In the performance data, faces learned as caricatures were recognized more accurately than faces learned as veridicals. In the ERP data at learning, N250 and a late-positive component (LPC) were largest for shape caricatures. At test, LPC was largest for faces that had been learned as texture caricatures. Overall, our findings indicate that initial encoding of distinctive facial shape or texture generalizes to and, importantly, facilitates recognition of veridicals.

43.4097 **Scanning Faces During Encoding and Retrieval: Age and Race Effects** Gizelle Anzures[1](gianzures@ucsd.edu), Frank Haist[1,2]; [1]Center for Human Development, UC San Diego, [2]Department of Psychiatry, UC, San Diego

Past studies show differences in adults' visual scanning of own-race and other-race faces (reviewed in Anzures et al., 2013). However, few studies have examined such scanning in children, and past studies have not directly compared scanning across learning and recognition test phases. Thus, we sought to examine visual scanning of own- and other-race faces across the encoding and retrieval phases of a face recognition memory task in adults and children. Caucasian participants completed a computerized face recognition task with Caucasian and Asian faces (blocked by race) while their eye scanning was recorded. Familiarization comprised of 10 sequentially presented male and female adult faces. Test immediately followed, during which target faces were shown in novel facial poses and intermixed with distractor faces. Participants made old/new judgments with button presses. Preliminary results with 19 young adults and 14 seven- to 11-year-olds reveal stimulus race and participant age effects. However, stimulus race effects did not differ across familiarization and test (p values > .10). Adults and children alike showed an overall greater proportion of looking at the eyes, nose, and mouth of own-race than other-race faces ($p < .05$). Participants also showed greater looking at the eyes of own-race than other-race faces, whereas they showed greater looking at the nose and mouth regions of other-race than own-race faces

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(p values < .01). In addition, participants showed a greater proportion of scanning transitions from the nose and mouth regions of other-race than own-race faces (p < .05). Despite comparable stimulus race effects across adults and children, participant age effects were evident. Adults showed greater overall looking at the eyes, nose, and mouth regions of faces compared to children (p < .05). Children also demonstrated fewer scanning transitions across the left and right eyes compared to adults (p < .01).

43.4098 Dustin Hoffman Then and Now: The Age Invariance of Familiar Face Representations is Dependent on Experience.

Sarah Laurence[1](s.k.laurence@keele.ac.uk), Valentina Proietti[2], Catherine Mondloch[2]; [1]School of Psychology, Keele University, [2]Department of Psychology, Brock University

Our representations for familiar faces are thought to be invariant to changes in their appearance. However, one aspect of invariance that has received little attention is whether our familiar face representations are invariant to the changes brought about by aging. Young and Bruce (2011) pose the question "Do we have one FRU for Paul McCartney when he was in the Beatles and one for when he was 64, or what?" (p. 970). The current study was designed to explicitly test this question using Face Identity Aftereffects. Young and older adults were adapted to two familiar celebrities (e.g., Paul McCartney and Steve Martin); the adapting faces were young on some trials (e.g., Paul McCartney when he was in the Beatles) and old in others (e.g., Paul McCartney from the present day). They subsequently made 2AFC identity decisions with morph faces (e.g., 50% McCartney/50% Martin) that were young on some trials and old on others. Data-to-date (n= 30 Young adults; n = 22 Older Adults) suggest that young adults show adaptation only when the age of the adaptor matches the age of the test faces. Older adults, like young adults, show adaptation when the age of the adaptor matches the age of the test faces, but also when the adaptor is an old face and the test faces are young. These findings have implications for our representations of familiar faces and how these representations change across time. Young adults who learned both young and old celebrity faces simultaneously (i.e., who were not alive for Beatlemania) appear to store separate representations whereas older adults, who aged with the celebrities, appear to have a more integrated representation with some asymmetry in the relation between current (old) and past faces.

43.4099 Personal familiarity enhances sensitivity to horizontal structure during face identification

Matthew Pachai[1,2](mattpachai@gmail.com), Allison Sekuler[2], Patrick Bennett[2], Philippe Schyns[3], Meike Ramon[4]; [1]Brain Mind Institute, Ecole Polytechnique Fédérale de Lausanne, [2]Department of Psychology, Neuroscience & Behaviour, McMaster University, [3]Institute of Neuroscience and Psychology, University of Glasgow, [4]Département de Psychologie, Université de Fribourg

Recent evidence suggests that the structure conveyed by horizontally-oriented spatial frequency components is maximally diagnostic for face identity, and that selective processing of this structure is correlated with face identification performance (Pachai et al, Front Psychol, 2013). Given that processing of facial information for identification and discrimination is more efficient for personally familiar than unfamiliar faces (e.g., Bruce et al, JEP:A, 1999; Ramon, PeerJ, 2015; Ramon & Van Belle, PeerJ, in press), we hypothesized that personal familiarity would be associated with higher horizontal selectivity in a face identification task. To assess this hypothesis, we recruited observers from the University of Glasgow and McMaster University to complete an identification task using members of the School of Psychology at University of Glasgow as stimuli. These two groups were matched in age, sex, and years of education, differing only in their personal familiarity with the stimuli. Across trials, we presented upright or inverted faces that were horizontally or vertically-filtered with bandwidths ranging from 15-180°. For each observer, we fit psychometric functions relating proportion correct to the entire range of filter bandwidths, separately for each face and filter orientation. From these fits, we defined horizontal selectivity as the difference between horizontal and vertical filters from 15-90°, where 90° represents the maximum independent bandwidth, and overall identification accuracy as performance with 180° filters, where 180° represents unfiltered stimuli. Our results revealed higher identification accuracy for familiar faces than unfamiliar, with a non-significant effect of familiarity on the difference between upright and inverted stimuli. We also found higher horizontal selectivity for familiar faces than unfamiliar, but only when the stimuli were upright. Together, these results suggest that personal familiarity increases the selective processing of horizontal structure from face stimuli, particularly when the faces are presented at the canonical orientation encountered during everyday life.

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43.4100 How does a newly encountered face become familiar?

Kristen Baker[1](kb09gi@brocku.ca), Sarah Laurence[2], Catherine Mondloch[1]; [1]Psychology, Brock University, [2]Psychology, Keele University

Most studies of face recognition use tightly controlled images but in the real world extrinsic (e.g., camera, lighting) and intrinsic (e.g., make-up, viewpoint) factors influence the appearance of a face. Two pictures of the same person can look very different and pictures of two different people can look very similar. Adults easily recognize familiar faces despite within-person variability in appearance, but frequently perceive two photos of an unfamiliar identity as belonging to different people (Jenkins et al., 2011), an error that is more common in children (Laurence & Mondloch, 2015). We examined the process by which a newly encountered face becomes familiar. In Experiment 1 adults (n=72) watched a 10-minute video in which a model read a storybook as filmed on a single day (low variability, LV) or across three days to incorporate variability in intrinsic and extrinsic factors (high variability, HV). Participants then were given a pile of novel photographs and asked to find all of the pictures of the model (n=9). Both training groups recognized more photos (Ms=7.0 [HV] and 6.8 [LV]) than the no-training control group (M=5.4), ps< .01, with no effect of condition on false alarms (misidentifying a similar looking distractor as the model). In Experiment 2 we assessed the effects of variability and training duration; MTurk workers (n=288) watched a 1- or 10-minute video in the HV or LV condition. Accuracy was not affected by either variable, ps>.20. We conclude that dynamic stimuli (which more closely resemble how we learn faces in daily life) incorporate sufficient variability to support face learning and that adults learn faces efficiently. An ongoing study with children (aged 6 to 12 years; n = 36 to date) suggests they learn less efficiently than adults.

Acknowledgement: NSERC

43.4101 FFA activity predicts face recognition performance

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The presence of a stable and predictable relationship between brain activity and behavioral performance is the foundation for research in face and object recognition. McGugin et al (2012) showed that for car experts, activation in FFA for cars is strongly correlated with behavioral performance for recognizing those objects. However, a similar correlation is not observed between FFA activity for faces and face recognition performance in the normal population (Furl et al., 2011). It is likely that for typical individuals, face recognition performance is at ceiling because experience with faces is saturated, therefore, abolishing a correlation between FFA activity and performance. We examine whether it is possible to observe a correlation between face recognition ability and activation in the FFA by utilizing a novel race of faces ("Lunaris," Chua et al., 2014) for which experience can be manipulated. We trained 25 participants to individuate Lunari faces and manipulated the amount of training to induce a wide range of performance across our participant pool. We used to examine the effects of manipulated experience during a 1-back task with Lunari faces, Caucasian male faces, and objects. Responses for Caucasian faces was not significantly correlated with face recognition performance (rFFA2: r = .10, lFFA2: r = .19 .19, lOFA: r = 0) as seen in previous research. However, responses for Lunari faces was significantly correlated with Lunari face recognition performance across the same ROIs (rFFA2: r = .50, lFFA2: r = .43, lOFA: r = .50, p < .05 across all ROIs). Our results provide evidence for a single mechanism underlying visual recognition abilities, and further, that visual recognition performance is modulated by the level of experience with a particular class of objects or faces.

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43.4102 The influence of hometown population on the relationship between face memory and holistic processing

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Enhanced experience with specific face categories (e.g., race) and visual deprivation can influence long-term face recognition abilities. Currently, we examine whether limited face exposure during development, resulting from growing up in a depopulated area, may also affect face processing. Participants from very depopulated areas are a unique population that allows us to study face deprivation in the absence of visual deprivation. Previously, we have shown that these individuals have poorer face memory for unfamiliar faces relative to control participants, and here we examine if

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their reduced experience with faces also leads to a differential relationship between face memory and holistic processing. We recruited participants from small (< 1000 persons, N=21) and large (>30,000 persons, N=20) communities and used two measures to characterize face recognition abilities: (1) The Cambridge Face Memory Test (Duchaine & Nakayama, 2006) and (2) The Vanderbilt Holistic Processing Test – Faces 2.1 (VHPT, Richler, Floyd, & Gauthier, 2014). We asked participants to complete both tasks, as well as the Cambridge Car Memory Test (CCMT) so that we could determine how holistic face processing and object memory predicted face memory performance across groups. For large-town participants, a multiple regression analysis revealed a significant linear relationship between the CCMT, the VHPT, and face memory performance (R2 = 0.58, p = 0.0016). Critically, holistic processing performance was a significant negative predictor of CFMT performance for individuals from large towns. For participants from small towns, we did not observe a significant relationship between our predictors and CFMT performance (R2 = 0.19, p = 0.29). These results suggest that the strategies and representations employed for face recognition may differ across our participant groups. In particular, we suggest that observers from depopulated regions may have more idiosyncratic mechanisms supporting face memory performance than observers with greater face experience.

43.4103 **Learning to Recognize Faces Following Perceptual and Conceptual Judgments** Linoy Schwartz[1](linoy.schwartz@gmail.com), Galit Yovel[1,2]; [1]The Sagol School of Neuroscience, Tel-Aviv University, [2]The School of Psychological Sciences, Tel Aviv University

While recognition of familiar faces is extremely good, the recognition of unfamiliar faces is prone to many errors. These differences could be accounted for by either perceptual or conceptual knowledge that we have about familiar, but not unfamiliar faces. Since both factors are confounded in familiar faces, the sole contribution of perceptual or conceptual information can only be examined by using either of these factors during face familiarization. In a set of experiments, participants were asked to learn unfamiliar faces while rating them based on either their perceptual, physical features or based on their inferred personality traits. Findings show that learning faces using conceptual judgments yielded much better recognition than learning faces based on perceptual judgments. This effect was found both when perceptual questions included holistic facial aspects (e.g. is the face symmetric?) or when they asked about specific facial features (e.g., how thick are the eyebrows?). Interestingly, conceptually learned faces were more resilient to changes in viewpoint and illumination than perceptually learned faces. Furthermore, recognition of low-resolution, degraded images of the learned faces was better following face learning with conceptual than perceptual judgments. Finally, we tested whether conceptual judgments are mediated via previous experience, using the same design with other-race faces. Interestingly, no advantage for conceptually than perceptually learned faces was found for other-race faces, suggesting the important role of previous experience in associating semantic information to faces. These findings suggest that associating semantic meaning to newly learned faces, rather then focusing on their perceptual aspects, enhances their perceptual representation and improves face recognition. These findings suggest that conceptual information is likely to play an important role in our superior recognition of familiar faces.

43.4104 **The role of motion in familiar and unfamiliar recognition of the whole person** Noa Simhi[1](noa.louisa@gmail.com), Galit Yovel[1,2]; [1]The School of Psychological Sciences, Tel Aviv University, [2]The Sagol School of Neuroscience, Tel-Aviv University

What is the role of motion in person recognition? Dynamic identity signatures (DIS), or unique idiosyncratic movements of different individuals, have so far been examined in the context of facial motion in search of their possible contribution to face recognition. In particular, it has been suggested that DIS may contribute mainly in familiar person recognition (O'Toole, Roark, & Abdi, 2002). However, despite the fact that studies have shown that following exposure to motion, the body improved person recognition beyond the face (O'Toole et al., 2011; Simhi & Yovel, 2015), the specific role of DIS in familiar and unfamiliar whole person recognition has not been examined so far. Furthermore, in the context of whole person recognition the role of DIS, and their advantage over static information, has been examined mainly in point-light displays, which differ substantially from natural viewing conditions. In a set of experiments we therefore assessed the role of DIS in unfamiliar and familiar person recognition using naturalistic videos. To assess the role of DIS in unfamiliar person recognition, we used a sequential matching task in which participants study videos of the whole person and perform person recognition from either videos or still images. We found that DIS did not contribute to unfamiliar person recognition beyond static images of the whole person. We further examined the role of DIS after undergoing extensive familiarization with different dynamic identities. We found that after familiarization recognition from videos was better than recognition from still images alone indicating that while DIS may not usually contribute to unfamiliar person recognition they can contribute to whole person recognition of familiar people. These findings highlight the importance of considering the role of motion in whole person recognition and in particular the role of motion in familiar person recognition.

43.4105 **Rapid category learning in high-level vision: From face instances to person categories** James Tanaka[1](jtanaka@uvic.ca), Alison Campbell[1]; [1]Department of Psychology, University of Victoria, British Columbia, Canada

A face varies in its retinal properties due to fluctuations in orientation, surface lighting and viewing distance. A person's facial appearance can be altered by makeup or changes associated with age and health status. Successful face recognition therefore requires that the range of face instances be correctly categorized as belonging to the same person. However, the perceptual factors governing this visual categorization process are not well understood. We hypothesized that person representations can be abstracted from a rapid and structured stream of face presentations. Using the RSVP method, participants passively viewed a continuous sequence of 160 different grey scale photographs of four Dutch female celebrities (40 photographs per celebrity). The photographs were centrally presented unmasked every 500 ms. In the blocked condition, the photographs were grouped by celebrity (e.g., 40 images of Celebrity A, 40 images of Celebrity B, etc.). In the mixed condition, the photographs were presented in random order. After two rounds of presentations, participants completed a "same/different" test in which two celebrity photographs were sequentially presented for 500 ms, each followed by a visual mask. Participants responded "same" if the photographs depicted the same celebrity or "different" if the photographs depicted two different celebrities. The test faces were novel and not seen during the presentation phase of the experiment. The main finding was that participants in the blocked presentation condition performed reliably better on the same/different task (d' = 2.21) than participants in the mixed presentation condition (d' = 1.74, p < .05) and participants in a no-presentation control condition (d' = 1.41, p < .001). Performance of participants in mixed and control conditions did not reliably differ, p > .10. These results suggest that the rapid presentation of many face instances, grouped by category promotes the efficient formation of person representations.

43.4106 **Face and body recognition in dancers and non-dancers** Larissa Vingilis-Jaremko[1](vingilis@yorku.ca), Victoria Guida[1], Karolina Beben[1], Grace Gabriel[1], Joseph DeSouza[1]; [1]York University

The ability to recognize others is critical to our everyday social interactions. Although extensive research has explored the role of the face for person recognition, little has explored the role of the body, which may be used for recognition at a distance. Because bodies may be processed similarly to faces (Rhodes, Jeffery, Boeing, & Calder, 2013; Robbins, Coltheart, 2010; Robbins, Coltheart, 2012), we explored whether body recognition abilities are influenced by visual experience, as are face recognition abilities. We tested two groups with different types of visual experience with bodies: dancers (n=29), who spend much of their time observing and comparing bodies in form fitting clothing to achieve a physical aesthetic, and non-dancers (n=37), who tend to see bodies in more obstructive clothing and spend less of their time viewing bodies. Participants viewed images of bodies wearing identical clothing, and after a short break, selected which body from a pair of bodies they had seen before. Participants completed the same task with faces in a separate, counterbalanced block. We hypothesized that dancers would have better accuracy at recognizing bodies, but perform similarly to non-dancers at recognizing faces. First, we found that participants recognized faces better than bodies (p< 0.001), consistent with previous research (Burton, Wilson, Cowan, & Bruce, 1999). Additionally, we found that dancers recognized faces and bodies better than non-dancers (main effect of participant group, p=0.043). These results suggest that dancers are more accurate at recognizing identity using the body than non-dancers, possibly because of their extensive visual experience with bodies. More accurate face recognition abilities among dancers could result from facilitation effects across brain networks, as bodies and faces are typically seen together.

43.4107 **The Own-Race Recognition Advantage is Attributable to Visual Working Memory: Evidence from a continuous-response paradigm** Xiaomei Zhou[1](vz12ep@brocku.ca), Catherine Mondloch[1], Stephen Emrich[1]; [1]Department of Psychology, Brock University

Considerable research examining the other-race effect (e.g., better recognition of own-race than other-race faces) has proposed that impaired recognition of other-race faces can be attributed to the inefficient storage and retrieval of other-race face representations from memory. However, little is known about the precision with which own- versus other-race faces are mentally represented in visual working memory (VWM). To address the question, we used a continuous-response paradigm and a mixture model to independently measure the precision (sd) and number of own-and other-race face representations stored in VWM. We created a set of Caucasian and Asian face stimuli by morphing between all possible pairings of four Caucasian and four Asian identities. In the experiment, two morphed faces, cued by different colors, were presented for 1500 ms and followed by a 900 ms delay. Participants then were instructed to recall one of the two faces (i.e., target face cued by a specific color) from memory by clicking the target face from a "face wheel", comprising four anchor faces and a morphed continuum between adjacent pairs (e.g., A-B; B-C; C-D; D-A). Based on the mixture-model analysis, the number of other-race face representations correctly reported (M = 57.4%) was reduced compared to that of own-race faces (M = 77.9%). However, the precision of those representations was comparable for own- and other-race faces (Msd = 35.40 and 33.23, respectively), as was the probability of incorrectly selecting the non-target face (discrimination error) (Me = 0.19% vs. 0.17%, for own- and other-race faces, respectively). The current study provides direct evidence of a fundamental difference in how own- and other-race faces are represented in visual working memory and highlights the functional role of perceptual experience in shaping such representations.

Acknowledgement: NSERC

43.4108 Improving other-race face recognition: Modifying representations in multi-dimensional face space. Claire Matthews[1](cm10ph@brocku.ca), Catherine Mondloch[1]; [1]Department of Psychology, Brock University

The own-race recognition advantage has been attributed to other-race faces being densely clustered in multi-dimensional face space (Valentine, 1991) rendering discrimination especially difficult. However, training protocols that emphasize discrimination (between-person variability) had only modest effects (McGugin et al., 2011). Relying on tightly controlled images ignores another important challenge: recognizing identity despite within-person variability in appearance (make-up, expression, viewpoint, lighting). When faces are unfamiliar, two images of the same identity often are perceived as belonging to different people, especially when viewing other-race faces (Laurence et al., 2015), perhaps because they have smaller attractor fields (Tanaka et al., 1998). We hypothesized that incorporating both between- and within-person variability among young Black female faces would increase training effectiveness. During training, Caucasian participants (n=20 per group) learned either 1 image of 12 identities (between-person variability only) or 5 images of 6 identities (both between- and within-person variability) to criterion (100% correct). A control group (n=13) received no training. Before and after training participants made same/different judgments for pairs of novel identities (not seen during training) comprising two different pictures of the same identity or pictures of two different people. Identities were paired randomly and presented simultaneously. Accuracy (d') showed a modest improvement, p = .02, an effect driven by improved performance on same trials, p=.03. However, the magnitude of improvement did not vary across groups, p=.83, suggesting training was ineffective. In an ongoing study, we are investigating the impact of more intensive training by extending training over 5 days with new identities introduced daily. During test phases, identities are matched for physical description, stimuli are presented sequentially (to avoid image matching), and include both novel identities and new images of trained identities. These results have implications for models of perceptual expertise and our representation of faces in multi-dimensional face space.

Acknowledgement: NSERC

43.4109 Older adult faces in the young adults' eyes: attention towards identity cues eliminates the recognition advantage for young adult faces Valentina Proietti[1](vproietti@brocku.ca), Sarah Laurence[2], Catherine Mondloch[1]; [1]Department of Psychology, Brock University, [2]Department of Psychology, Keele University

Young adults typically recognize young adult faces more accurately than older adult faces (own-age bias [OAB]). However, most research on this topic has measured recognition memory for controlled images of different identities and participants typically are instructed to memorize faces during a study phase. We investigate the OAB for images incorporating within-person variability in appearance and examined whether making same/different judgements (i.e., focusing on identity cues) about face pairs during the study phase reduces the OAB. Young adults (n=24/group) completed an old/new recognition task after viewing a series of old and young faces. During the study phase, one group completed a perceptual matching task in which participants were required to decide whether two different pictures of older/young adult faces belonged to the same person or two different people. Participants in the control group viewed the same faces during the study phase but faces were presented sequentially and participants were instructed to remember them. In the identity matching task, there was no overall advantage for young faces. However, accuracy was higher for old compared to young faces on same trials (p=.031), but for young compared to older faces on different trials (p=.021). In the recognition task, participants in the control condition demonstrated the typical OAB (better memory for young relative to older faces [p=.042]); in contrast, the OAB was absent for participants who first completed the matching task (p=.491). The absence of the OAB in the identity-matching condition is attributable to identity matching improving performance for older (p=.002), but not young faces (p=.60), relative to the control condition. Collectively, these results suggest that the OAB is attributable to a failure to attend to identity cues in older faces rather than an inability to encode and store older adult faces.

43.4110 The Inversed Affective Learning and Its Cause Naixin Ren[1,2](rennx@psych.ac.cn), Wenfeng Chen[1], Xiaolan Fu[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, [2]University of Chinese Academy of Sciences

People can learn values of objects with only minimal exposure to mildly affective cues, which is known as minimal affective learning (Bliss-Moreau, Barrett, & Wright, 2008). The inclusion/exclusion (I/E) model in evaluative judgment assumes that the instant judgement of an object can be influenced by the enviromental information: information that can be used in forming a representation of the target results in assimilation effects; information that cannot be used in forming a representation of the target would results in contrast effects (Bless & Schwarz, 2010). In previous studies of minimal affective learning, affective stimuli, such as the sentences describing behavior in face-sentence pairs, can always be used to form the representation of the neutral objects. Hence, the I/E model provides an assimilation effect account for minimal affective learning. Following this rationale, if the affective stimulus cannot be used to represent the neutral object during affective learning, there would be a contrast effect. As a result, the neutral object would acquire the opposite value of the paired stimulus, which would lead to an "inversed affective learning", as defined in this study. To test this prediction, face pairs with varied facial attractiveness were adopted in two experiments. After being presented ordinary neutral faces paired with one (Experiment 1) or four (Experiment 2) attractive faces or unattractive faces four times, participants were asked to judge the valence of the isolated neutral faces. Experiment 1 revealed an inversed affective learning. Experiment 2 further demonstrated that there was a stronger effect when the affective stimuli are stronger. This study initially illustrates that neutral objects can acquire the opposite value from affective stimuli through a new minimal affective learning mechanism, and provided a new perspective to affective learning.

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43.4111 Measuring capacity for template precision in dual-target search for faces Tamaryn Menneer[1](t.menneer@soton.ac.uk), Natalie Mestry[1], Hayward Godwin[1], Kyle Cave[2], Nick Donnelly[1]; [1]Psychology, University of Southampton, UK, [2]Psychology, University of Massachusetts Amherst, MA, USA

Previously (VSS 2015) we presented data from two experiments showing a cost in dual-target search for two unfamiliar faces, in which accuracy was lower than searching for the faces separately. Guidance of attention towards target-similar items in dual-target search was very limited at most. In these experiments we manipulated the visual similarity of distractor faces to target faces using morphing. Here we replicate this pattern of findings in a third experiment using more discriminable faces, and a different methodology, multidimensional scaling, was used for classifying target-distractor similarity. Data from all three experiments are evaluated using our novel capacity measure that represents the utility, and therefore precision, of the template for each of the two faces. In addition to the dual-target cost in accuracy and response time, participants in all experiments focussed search on one of the targets in dual-target search at the expense of the other. In general, probability of fixation to distractors suggests unguided search for targets, with search becoming more exhaustive for the non-preferred target in dual-target search. However, there is some evidence for attentional guidance, with targets being fixated earlier than they would be under

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exhaustive search, although this guidance only occurred when target representations were strong and particularly when target-distractor similarity was low. Consistently across the experiments, results suggest capacity for target representation is limited in search for two unfamiliar faces, with one target face being prioritised. However, when faces were searched individually first, before the dual-target search, capacity for the non-preferred target in dual-target search increased, indicating that increased familiarity with the individual faces improves target representation precision in dual-target search. By examining changes in capacity for target representation, our novel capacity measure can provide insights into target representations in dual-target search, and also into the process of face learning.

43.4112 **Deliberate disguise in facial image comparison** Eilidh Noyes[1](ecn508@york.ac.uk), Rob Jenkins[1]; [1]Department of Psychology, University of York, York, UK

Face identification performance is very different for familiar and unfamiliar faces. Unfamiliar viewers typically perform poorly even in paired matching tasks, whereas familiar viewers perform with very high levels of accuracy. However, these standard results are based on studies in which the person being identified is cooperating with the effort to identify them. In the real world, people may have strong incentives to avoid identification by disguising themselves. Here we ask whether familiarity with a face can help the viewer see through a disguise. We distinguish between two different types of disguise—Evasion (trying not to look like oneself) and Impersonation (trying to look like a specific target person). To capture this distinction, we gave 26 volunteer models (i) a photo of themselves, and asked them to make themselves look unlike that reference photo for a subsequent shoot (Evasion condition), and (ii) a photo of someone else, and asked them to make themselves look like that person (Impersonation condition). We then constructed a face-matching task based on disguised and undisguised images of these models, and presented the resulting face pairs to 60 unfamiliar and 30 familiar viewers. Unfamiliar viewers made significantly more errors overall when matching disguised faces (m = 78% correct) compared with undisguised faces (m = 94% correct), with Evasion disguises proving especially challenging (m = 60% correct). Interestingly, performance for unfamiliar viewers was equivalent whether they were informed of the disguise manipulation or not. Familiar viewers were much more accurate for disguised faces (m = 93% correct) and also for undisguised faces (m =97% correct) but still committed errors in the Evasion condition (m = 86% correct). Our findings help to delineate strengths and limitations of familiar face recognition. They also have implications for face identification in security and forensic settings where disguises are commonly used.

43.4113 **Optimal integration of facial form and motion during face recognition** Katharina Dobs[1,2,3](katharina.dobs@cerco.ups-tlse.fr), Isabelle Bülthoff[3], Leila Reddy[1,2]; [1]Université de Toulouse, Centre de Recherche Cerveau et Cognition, Université Paul Sabatier, Toulouse, France, [2]CNRS UMR 5549, Faculté de Médecine de Purpan, Toulouse, France, [3]Max Planck Institute for Biological Cybernetics, Dept. Human Perception, Cognition and Action, Tübingen, Germany

Integration of multiple sensory cues pertaining to the same object is essential for precise and accurate perception. The optimal strategy to estimate an object's property is to weight sensory cues proportional to their relative reliability (i.e., the inverse of the variance). Recent studies showed that human observers apply this strategy when integrating low-level unisensory and multisensory signals, but evidence for high-level perception remains scarce. Here we asked if human observers optimally integrate high-level visual cues in a socially critical task, namely the recognition of a face. We therefore had subjects identify one of two previously learned synthetic facial identities ("Laura" and "Susan") using facial form and motion. Five subjects performed a 2AFC identification task (i.e., "Laura or Susan?") based on dynamic face stimuli that systematically varied in the amount of form and motion information they contained about each identity (10% morph steps from Laura to Susan). In single-cue conditions one cue (e.g., form) was varied while the other (e.g., motion) was kept uninformative (50% morph). In the combined-cue condition both cues varied by the same amount. To assess whether subjects weight facial form and motion proportional to their reliability, we also introduced cue-conflict conditions in which both cues were varied but separated by a small conflict (±10%). We fitted psychometric functions to the proportion of "Susan" choices pooled across subjects (fixed-effects analysis) for each condition. As predicted by optimal cue integration, the empirical combined variance was lower than the single-cue variances ($p < 0.001$, bootstrap test), and did not differ from the optimal combined variance ($p > 0.5$). Moreover, no difference was found between empirical and optimal form and motion weights ($p > 0.5$). Our data thus suggest that humans integrate high-level visual cues, such as facial form and motion, proportional to their reliability to yield a coherent percept of a facial identity.

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Monday AM

Eye Movements: Cognition and models

Tuesday, May 17, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Melissa Vo

51.11, *8:15 am* **Stuck on semantics: Irrelevant object-scene inconsistencies modulate ongoing eye movement behavior during letter search** Tim Cornelissen[1], Melissa Vo[1]; [1]Scene Grammar Lab, Goethe University Frankfurt

People have an amazing ability to identify objects and scenes within a glimpse of an eye. How automatic is this scene and object identification? Are scene and object semantics —let alone their semantic congruity— processed to a degree that modulates ongoing gaze behavior even if they are irrelevant to the current task? Objects that do not fit the semantics of the scene (e.g. a toothbrush in an office) are typically fixated longer and more often than consistent controls. In Experiment 1, we overlaid a letter T on photographs of indoor scenes and instructed fourteen participants to search for it. Some of the background images contained scene incongruent objects, but these provided no information about the target position. Despite their lack of relevance to the search, we found that subjects looked at incongruent objects longer and more often compared to congruent objects in the same position of the scene. In Experiment 2, we replicated these findings and — to better understand how aware participants had been of the objects — subsequently tested participants' memory for the critical objects in both a free recall and a 2AFC task. Participants did not remember more incongruent objects than congruent objects and performed no better than chance for incongruent objects during 2AFC suggesting that while being "stuck" the observers had no explicit memory of these objects. Attempting to diminish this object congruency effect, in Experiment 3 we overlaid a grid of search elements on the background images. Even though no longer statistically significant, the same pattern of results emerged for each measure of gaze behavior. Based on these results we argue that when we view natural scenes, scene and object identities are processed automatically. Moreover, even when irrelevant to our current search, a semantic mismatch between scene and object identity can modulate ongoing eye movement behavior.

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51.12, *8:30 am* **Perceptual and motor strategies for integrating information across graphs and accompanying text** Jason Rubinstein[1](j.rubinstein@rutgers.edu), Cordelia Aitkin[1], Eileen Kowler[1]; [1]Department of Psychology, Rutgers University-New Brunswick

Gathering and integrating information from spatially distinct and qualitatively different sources requires decisions about when and where to sample information. An example is reading graphs and accompanying text to arrive at a coherent interpretation. Observers inspected graphs depicting realistic data, along with associated text, in one of the following configurations: (1) Simultaneous: Graph and text were adjacent, requiring a saccade to switch between them; (2) Eye contingent: Graph and text appeared sequentially, with the appearance of each triggered by a saccade, and (3) Button-press: graph and text appeared sequentially, with the appearance of each triggered by a button press. Observers answered a true/false question based on the graph after 60s of viewing (response accuracy~70%). About twice as much time was spent reading the text as inspecting the graph, despite the greater utility of the graph in answering the t/f question, and even when text content was tangential to the graph. During the initial reading of text, Ss rarely stopped mid-passage to switch to the graph. The perceptual configuration and the motor action needed to switch between graph and text had surprisingly large effects. The average number of transitions/trial between graph and text was greater in the simultaneous (6.5 ± 0.5) than in either the eye-contingent (4.5 ± 0.5) or button-press conditions (3.3 ± 0.5). Corresponding mean durations of individual visits to graph or text were 7 s for simultaneous, 8.5 s for eye-contingent and 12 s for button-press conditions. These results show that strategies used to sample information from spatially-distinct, heterogeneous sources depend not only on the information value, but also on perceptual availability and motor effort. Preferences to avoid even modest increases in perceptual-motor cost may be useful in order to preserve limited resources for processing the content and meaning of the displays.

Acknowledgement: NSF 0549115

51.13, *8:45 am* **Using CRISP to model saccade parameters and error rates in the antisaccade task** Ryan Hope[1](hoper2@rpi.edu), Wayne Gray[1]; [1]Cognitive Science, Rensselaer Polytechnic Institute

A growing body of research on oculomotor control suggests that humans have much less control over their eye movements than typically assumed. Eye trackers have revealed that the eyes are in constant motion, even when fixating, and that these fixational eye movements are possibly functional. The growing consensus is that saccades are initiated automatically by a rhythmic trigger from the brainstem. An important question now is how does a system based on automatic (involuntary) saccade timing still allow for top-down (voluntary) control? The CRISP model of saccade generation, which models the saccade timer as a random walk process, proposes two mechanisms for control; cognitive processes can affect the rate of the saccade timer and potentially cancel ongoing programming. The present work tests whether these two mechanisms are sufficient for capturing the complex saccadic behavior observed from humans performing the antisaccade task, a task specifically designed to elicit eye movements that are incompatible with top-down goals. We hypothesize that these two mechanism will not be sufficient to reproduce human behavior and propose that a spatial mechanism needed. In order to test this hypothesis, the parameter space of the baseline CRISP model as well as two variant models (one with a bottom-up saliency driven saccade target map and one with a top-down attention driven saccade target map) were explored to see if the distribution of saccade parameters (e.g. latency and amplitude) could be generated that were consistent with those generated by humans performing the antisaccade task. As predicted, the spatial models were able to replicate the distributions of saccade parameters and error rates for 18 human subjects who performed a mixed-block antisaccade task. These results suggest that top-down control with automatic saccade timing is accomplished by influencing the spatial component of the eye movement.

51.14, *9:00 am* **Reading without a lexicon: An illiterate model of saccade programming in the superior colliculus predicts where readers move their eyes!** Françoise Vitu[1](Francoise.Vitu-Thibault@univ-amu.fr), Hossein Adeli[2], Gregory Zelinsky[2,3]; [1]Laboratoire de Psychologie Cognitive, CNRS, Aix-Marseille Université, [2]Department of Psychology, Stony Brook University, [3]Department of Computer Science, Stony Brook University

Most models of eye-movement control during reading assume that saccadic behavior primarily reflects ongoing word-identification processing. Here we show, in contradiction with this view, that an image-based model of saccade programming in the superior colliculus (SC) can predict the highly stereotyped saccadic behavior observed during reading, simply by averaging early visual signals. Twenty-nine French-native speakers read 316 French sentences presented one at a time on a computer screen, while their eye movements were recorded. Images of the sentences were input to the model. Like participants, the model initially fixated the beginning of each sentence. On each fixation, it first performed gaze-contingent blurring of the sentence to reflect visual acuity limitations. A luminance-contrast saliency map was then computed on the blurred image and projected onto the fovea-magnified space of the SC, where neural population activity was averaged first over the visual map and then over the motor map. Averaging over the most active motor population determined the subsequent saccade vector. The new fixation location was in turn inhibited to prevent later oculomotor return. Results showed that the model, like participants, mainly made left-to-right, forward saccades, with just a few (21% and 20% respectively) regressive saccades. The model also successfully captured benchmark, and here-replicated, word-based eye-movement patterns: a greater likelihood to skip shorter and nearer words, a preferred landing position near the centers of words, a linear relationship between a saccade's launch site and its landing site, a greater likelihood to refixate a word when the initial fixation deviated from the word's center, and more regressions following word skipping. Thus, eye movements during reading primarily reflect fundamental visuo-motor principles rather than ongoing language-related processes. The proof is that a model of the SC, which treats sentences as a meaningless visual stimulus, reproduces readers' eye-movement patterns, despite being unable to recognize words!

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51.15, *9:15 am* A dissociation between the perceptual and saccadic localization of moving objects for reactive saccades but not for memory-guided saccades Delphine Massendari[1](delphine.massendari@gmail.com), Matteo Lisi[1], Thérèse Collins[1], Patrick Cavanagh[1, 2]; [1]Laboratoire psychologie de la perception, CNRS UMR 824, Université Paris-Descartes, [2]Psychological and Brain Sciences, Dartmouth College, Hanover, NH

The double-drift stimulus leads to a large discrepancy between the physical path of a moving gabor and its perceived direction. Saccades directed to the double-drift stimulus land along the physical, and not perceived, path (Lisi & Cavanagh, 2015). Here we asked whether memory-guided saccades exhibited the same dissociation from perception. We used the same stimuli as in Lisi and Cavanagh (2015): a single gabor moving back and forth along a linear trajectory while its internal motion drifted in the orthogonal direction. During presentation, participants were asked to keep their eyes focused on the fixation dot, such that the drifting gabor was in the periphery. The gabor disappeared (four possible offset locations) and after a variable delay (0-1000 ms), the fixation dot was removed, serving as the go-signal to make the saccade to the remembered location of the offset. With no delay, we replicated the finding that saccades target the physical, and not perceived, location. However, with delays as short as 250 ms, saccade endpoints shifted towards the perceived location. Moreover, the longer the delay, the higher the probability that endpoints landed near the perceptual position. Our result shows that while reactive saccades target physical stimuli, memory-guided saccades target perceived stimuli.

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51.16, *9:30 am* The buildup of temporal anticipation revealed by microsaccades and eye-blinks Yoram Bonneh[1](yoram.bonneh@gmail.com), Uri Polat[1], Yael Adini[2]; [1]Department of Optometry, Bar-Ilan University, [2]Institute for Vision Research, Kiron, Israel

Background: Temporal regularities in the environment and especially rhythmic stimuli are known to facilitate the response to events that appear temporally in-phase with these regularities, presumably reflecting unintentional and implicit predictions about the time of upcoming events. However, not much is known about the underlying mechanisms, the buildup process, and the level of automaticity or dependence on behavioral responses. Here we used the time course of microsaccades, which are small involuntary saccades occurring during fixation, as well as eye-blinks, to explore the buildup of temporal anticipation and its underlying mechanisms. Method: In a set of experiments, observers (n=7) passively viewed and silently counted sequences of 90 high-contrast Gabor patches, briefly flashed in around 1 Hz repetition rate at fixation. To explore the buildup of temporal anticipation, we used two randomly interleaved inter-stimulus onset intervals that differed by 100, 200, and 500 ms in separate conditions. Results: We first found that the microsaccade and eye-blink rate modulations were entrained by a fixed stimulus repetition rate, with anticipatory inhibition that reached its maxima around stimulus onset. When two intervals were mixed, we found that repetition of the same interval shortened the microsaccade inhibition period for the corresponding stimulus, while a change of interval increased it, with a magnitude that changed systematically with the number of recent (4-5) preceding events. These results were obtained for all interval pairs, including a small interval difference of 100ms which observers did not notice, demonstrating the high precision of the anticipation mechanism and its independence of perceptual awareness. Conclusion: We interpret the results as reflecting an ongoing process that computes implicit temporal predictions based on the recent past. Rhythmic stimuli induce a gradual buildup and tuning of this predictive mechanism resulting in a proportionally faster processing and shorter microsaccade inhibition for in-phase stimuli.

Attention: Neural mechanisms

Tuesday, May 17, 8:15 - 9:45 am
Talk Session, Talk Room 2
Moderator: Fred Hamker

51.21, *8:15 am* Attentional modulation of pupillary light responses by microstimulation of the superior colliculus Chin-An Wang[1](josh.wang@queensu.ca), Douglas Munoz[1]; [1]Centre for Neuroscience Studies, Queen's University

Pupil size changes constantly, mainly to regulate the amount of light entering to the retina, with pupil constriction to luminance increases and dilation to luminance decreases. This illumination-dependent pupil modulation has thought to be independent from the top-down influence such as spatial attention. However, it was shown recently that pupil size is smaller when spatial attention is guided to bright, compared to, dark surfaces, demonstrating the attentional modulation on illumination-dependent pupillary responses, although the underlying neural mechanism is yet explored. The superior colliculus (SC) is a midbrain structure causally involved in various components of orienting, including spatial attention. Here, we examined the attentional modulation of illumination-dependent pupillary responses by microstimulation of the SC (~70 Hz, 400 ms, 4 – 30 μA). We hypothesize that microstimulation of a specific location in the SC map will enhance sensory processing at the corresponding region of space (mimicking spatial attention shifts), inducing the illumination-dependent pupillary response (smaller pupil size in bright, compared to dark, surfaces presented in the region). While requiring monkeys to maintain central fixation, we presented bright and dark surfaces in two different locations that matched either the stimulated SC site or a control location in the opposite hemifield. We found that SC microstimulation modulated pupillary light responses in a spatially selective manner, with enhanced illumination-dependent pupillary responses while stimuli presented at the location corresponding to the stimulated SC site. Our results provide direct evidence arguing that the SC is mediating the attentional modulation of pupillary light responses.

51.22, *8:30 am* Transcranial alternating current stimulation (tACS) reveals causal role of brain oscillations in visual attention Daniel Baldauf[1](baldauf@mit.edu), Nir Grossman[1], An-Ming Hu[1], Ed Boyden[1], Robert Desimone[1]; [1]McGovern Institute for Brain Research, MIT

We combined tACS with MEG recordings to directly test the causal role of local alpha oscillations in visual spatial attention. After stimulating occipital cortex in one hemisphere for 15min we used evoked responses to evaluate the effects of alpha entrainment on the attentional weighting of visual input (dot probes). Our data describe in detail the spatial specificity as well as the exact time course of lasting rhythmic entrainment in early visual cortex. By analyzing both phase and power spectra of the entrained rhythms we show how experimentally induced alpha rhythms lead to lasting inhibition and, in consequence, to suppressed visual responses. The specific stimulation setup and additional control experiments rule out alternative possibilities of stimulation effects by retinal activation, proving that it is the actual (direct) entrainment of extrastriate cortex the leads to attentional weighting.

51.23, *8:45 am* The Impact of Noise Correlations in Visual Cortex on Perceptual Performance Depends on their Origin Adrian Bondy[1,2](adrian.bondy@gmail.com), Bruce Cumming[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health, [2]Brown-NIH Neuroscience Graduate Partnership Program

Stimulus-independent spike-rate variability tends to be weakly correlated between neuronal pairs throughout sensory cortex. It is frequently suggested that these "noise" correlations (rsc) reflect the stochastic nature of sensory input pathways, from which it follows they place hard limits on the fidelity of sensory encoding. For an optimal linear decoder, correlations limit information when they follow a particular relationship with neuronal preferences (so-called "differential" correlation structure). However, rsc may also reflect shared input from signals that are centrally generated and potentially under voluntary control. If so, its impact on sensory encoding is unclear. We sought to directly test whether the structure of noise correlations in visual cortex reflects signals of central origin during perceptual decision making, by measuring rsc in contexts where task instruction changed but retinal input was fixed. We recorded population spiking activity in primary visual cortex (V1) of rhesus monkeys, while the subjects performed a coarse orientation discrimination task using filtered noise. The discriminanda were fixed in a given recording session but were varied between sessions. We found that rsc structure changed with the task even on zero-signal trials which were identical for all sets of discriminanda, indicating a central origin. Specifically, pairs of neurons which preferred the same orientation discriminandum were more highly correlated than pairs preferring opposite discriminanda, while pairs not well tuned for the task showed no modulation. At first sight, these changes appear to have a detrimental impact on the information capacity of the population, since they are nearly "differential" in structure. However, if downstream areas can distinguish inputs of central and peripheral origin, then the observed rsc structure no longer constrains the information limit. More complex models of the relationship between feedforward and feedback pathways in sensory processing are needed to determine when noise correlations between sensory neurons are truly information-limiting

51.24, *9:00 am* **A quantitative neuro-computational model of attentive receptive field changes in area MT** Fred Hamker[1](fred.hamker@informatik.tu-chemnitz.de), Alex Schwarz[1]; [1]Chemnitz University of Technology

Visual spatial attention has been shown to modulate the receptive fields (RFs) of cells in cortical area MT (Womelsdorf et al., Nat Neurosci, 2006, Anton-Erxleben et al., Cereb Cortex, 2009). Former models of attention are typically too qualitative or too simple (e.g. Gaussian model by Womelsdorf et al., J Neurosci, 2008) to capture all observations made. Thus, we mathematically derived a neuro-computational model of interacting MT neurons and fitted the free parameters to the individual electrophysiological cell measurements from macaque area MT of Womelsdorf et al. (2006) and Anton-Erxleben et al. (2009). The model has been derived from a biologically plausible representation of neuronal connections, whilst considering the excitation from the stimulus as well as the lateral divisive-inhibition from MT-cells responding to two distractors, additionally presented in the RF, moving in the anti-preferred direction of the recorded cell. The RF is parameterized as an elongated Gaussian shape. Attention is propagated multiplicatively to all MT-cells in a certain range according to a radial Gaussian function. The proposed divisive-inhibition model is showing effects of attentional shift, shrinkage and expansion when attending inside or close to the receptive field based on the strength and width of attention. Due to these effects we simulated a virtual "compression" experiment (Ross et al., Nature, 1997, Kaiser & Lappe, Neuron, 2004) using all fitted model neurons of the MT cells and setting the attention signal to a single location for all cells (the virtual saccade target). We then decoded the population response of all model MT cells for position in the attended and non-attended case, given a flashed stimulus. If we compare the attended and non-attended case we observe the typical "compression" pattern of mislocalization, which suggests that "compression" emerges by the attentive tuning of the neural response of a large number of individual cells.

Acknowledgement: US-German collaboration on computational neuroscience. BMBF 01GQ1409

51.25, *9:15 am* **Understanding the impact of different sources of variability on IT performance during target search** Noam Roth[1](noamroth@mail.med.upenn.edu), Nicole Rust[1]; [1]Department of Psychology, University of Pennsylvania

Task performance is determined not only by the amount of task-relevant "signal" present in our brains, but also by the presence of "noise", which can arise from multiple sources, such as trial variability (variability under seemingly identical conditions) and nuisance variability (variability that results from changes in the world that are irrelevant for a task). While trial variability is known to be approximately described by a Poisson process, nuisance variability is much less well-understood. To investigate the relative impact of trial and nuisance variation on performance for one complex visual task, we recorded neural responses in inferotemporal cortex (IT) as two monkeys performed an "invariant delayed match to sample task" that required them to sequentially view images and identify when a "target match" appeared despite variation in the objects' positions, sizes and background contexts. Consistent with a representation of target match information in IT, a linear population read-out of the same images presented as target matches versus as distractors (invariant to nuisance variables such as object identity) performed robustly and this IT read-out systematically misclassified conditions when the monkeys made errors. To determine the relative impact of different sources of variability on IT target match performance, we reformulated a measure of single-neuron task performance (d') as a function of the firing rate modulation attributed to signal, trial variability and nuisance variation. Somewhat counterintuitively, we found that the modulations resulting from a subset of nuisance variables were larger than trial variability; however, the overall impact of nuisance variation on d' was much smaller. This is because the impact of nuisance variation depended on the pooled (average) variance, rather than the sum, introduced by all nuisance parameters. These results reveal that even in the presence of large sources of nuisance variation, trial variability can be the primary factor in limiting task performance.

Acknowledgement: National Eye Institute Grant R01 EY-020851

51.26, *9:30 am* **The Neural Bases of Mental Operations in Visual Working Memory** Peter Tse[1](peter.tse@dartmouth.edu), Prescott Alexander[2], Alex Schlegel[3]; [1]Dartmouth College, [2]UC Davis, [3]UC Santa Barbara

Background: In Baddeley's (1986) model of working memory, the brain manipulates mental representations via a central executive system that directs activity in subsystems like the visuospatial sketchpad. Many neuroimaging studies implicate a network including dorsolateral prefrontal cortex (DLPFC) and posterior parietal cortex (PPC) as the neural correlate of this model (e.g. Schlegel, et al., 2013). Current understanding suggests that DLPFC acts as Baddeley's central executive, directing transformations of mental representations in other regions rather than storing representations directly. For instance, Crowe and colleagues (2013) showed that neurons in monkey prefrontal cortex transmit executive control signals to parietal neurons. Question: In our fMRI studies, we asked whether DLPFC, PPC and other areas direct the manipulation of mental imagery or if they are also involved in representing mental images themselves. Method: We developed a hierarchy of abstract shapes and an orthogonal hierarchy of mental operations that could be performed on those shapes. In each of a series of trials, human participants performed a particular mental operation on a particular shape. Results: Using multivariate pattern classification methods on neural activity in DLPFC, we could decode both the shape that participants imagined and the mental operation that they performed. Representational similarity analyses showed that the informational structures of both DLPFC and PPC correlated significantly with both the shape and the operation hierarchies, although DLPFC correlated more with the operation hierarchy and PPC correlated more with the shape hierarchy. Conclusion: Our results suggest that information about both mentally imaged shapes and mental operations over those operands is distributed throughout specialized nodes of the frontoparietal network rather than localized to particular regions.

Color and Light: Surfaces and materials

Tuesday, May 17, 10:45 am - 12:30 pm
Talk Session, Talk Room 1
Moderator: Roland Fleming

52.11, *10:45 am* **Specular kurtosis and the perception of hazy gloss** Pascal Barla[1](pascal.barla@inria.fr), Peter Vangorp[2], Carlos Zubiaga[1], Roland Fleming[3]; [1]Inria Bordeaux, [2]Bangor University, [3]Giessen University

Previous work on the perception of glossy materials has mostly focused on two dimensions: gloss strength and microscale roughness. However, more advanced reflectance models often include additional parameters for controlling the distribution of reflected light. It remains unknown whether these additional dimensions have a perceptually significant influence on appearance. In particular, among the six types of gloss suggested by Hunter in his seminal book (Hunter, 1975), "haze" remains among the less studied of potentially pertinent material cues. From a physical point of view, hazy reflections are associated with heavy-tailed, or leptokurtic, reflectance functions, as often occurs in semi-polished metals or coated materials. We have investigated gloss haze by rendering movies of irregularly shaped objects made of metallic materials exhibiting more or less leptokurtic reflectance functions. We modeled hazy metals using a two-layered glossy material model with two centered Gaussian-like lobes (Ward, 1992) of different spread. Varying both the (1) relative spread and (2) relative magnitude of the two lobes yielded a 5x5 array of different materials. Subjects rated the following qualities for each material: glossiness, blurriness, haziness, coatedness, polish, and friction. Principal component analysis of the results reveals that haziness is a distinct visual dimension orthogonal to the commonly studied glossiness and blurriness. Coatedness appears to be nearly synonymous with haziness, as this is one of the main physical causes of haze in real world materials. Polish seems to be a combination of glossiness and haziness, as materials go from dull to hazy to highly glossy during the physical polishing process. The inferred tactile quality of friction is apparently uncorrelated with haziness. Our results demonstrate that haze is indeed a distinct perceptual dimension of gloss, which is systematically related to the kurtosis of the specular lobe.

Acknowledgement: EU Marie Curie Initial Training Network

52.12, *11:00 am* **Simultaneous gloss contrast: Conjoint measurements of lightness and gloss** Sabrina Hansmann-Roth[1], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Département d'Études Cognitives, École Normale Supérieure, Paris, France

In the simultaneous contrast effect, lightness judgments of a central patch are affected by surrounding surfaces of different luminance. Similar contextual effects in gloss perception have not been extensively studied yet because past experiments have mainly focused on only one material property (Fleming et al., 2003; Doerschner et al., 2010). We used a Maximum Likelihood Conjoint Measurement (Luce & Tukey, 1964; Knoblauch & Maloney, 2012, Chapt. 8) procedure that allows us to quantify simultaneously how two different contextual features (luminance and gloss) can

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potentially influence perceived lightness and gloss of the central surface. We rendered a glossy mid gray surface as the center and presented it surrounded by various backgrounds. Background images were chosen randomly out of 25 possible images (5 luminance levels × 5 gloss levels). In two experiments participants were presented with two images consecutively and they were either asked to indicate which center was lighter (Experiment 1) or which center was glossier (Experiment 2). We used the additive model of MLCM, assigned perceptual scale values to each lightness and gloss level of the background, and modeled the contribution of both features to the central surface. We found the standard simultaneous contrast when judging the lightness of the center. A lighter background produced a darker appearance of the center. Having a glossy background enhanced a little this simultaneous contrast. For gloss judgments, we found a strong assimilation effect: perceived gloss of the center increased with glossy backgrounds. In addition, participants could not ignore the lightness of the background when judging gloss. Lighter backgrounds reduced perceived gloss of the center, indicating that participants are influenced by the simultaneous lightness contrast when judging gloss. To conclude, conjoint measurements lead us to a better understanding of contextual effects in gloss perception and the role of gloss in the standard simultaneous contrast.

Acknowledgement: Funded by: EC FP7-PEOPLE PITN-GA-2012-316746 (PRISM)

52.13, *11:15 am* **Perceived 3D Shape Toggles Perceived Glow** Minjung Kim[1,2](minjung.kim@nyu.edu), Laurie Wilcox[1], Richard Murray[1]; [1]Centre for Vision Research & Department of Psychology, York University, Toronto, [2]Department of Psychology, New York University

Most surfaces reflect light from external sources, but others emit their own light, or glow. Glowing surfaces often signify an important feature in the environment (e.g., heat source or bioluminescent life form), but we know little about how the visual system identifies them. Here, we show that perceived 3D shape is critical for perceived glow. In Experiment 1, we created "dark-means-deep" stimuli by rendering stereoscopic pairs of wavy 3D surfaces under diffuse light (non-directional lighting on a cloudy day). This generated stimuli with bright peaks and dark valleys. We created "bright-means-deep" stimuli by using the same luminance images, but reversing the disparity to get dark peaks and bright valleys. Subjectively, dark-means-deep stimuli appeared evenly lit from the front, whereas bright-means-deep stimuli produced a vivid impression of glow. On a mirror stereoscope, we displayed dark-means-deep and bright-means-deep stimuli side-by-side, and asked observers to choose the one that appeared to glow. Five of six observers consistently identified the bright-means-deep stimuli as glowing. In a follow-up study, we assessed depth percepts for the same observers and stimuli using a depth-probe task ("is the probe on a peak or in a valley?"). Five of six observers performed almost perfectly. The sixth observer (the anomalous observer from above) ignored disparity cues, always judging bright regions as peaks and dark regions as valleys. Thus, this observer was anomalous because disparity cues did not affect their shape percepts. In Experiment 2, we used the same observers, stimuli, and methods, except that we used motion parallax instead of disparity to reveal surface relief. All observers, including the anomalous one, identified bright-means-deep stimuli as glowing, demonstrating that the glow effect was not tied to a particular depth cue. Our results demonstrate that human vision has a sophisticated understanding of lighting geometry, interpreting complex shape-luminance relationships to identify glowing surfaces.

Acknowledgement: NSERC Discovery Grant, NYU MacCracken

52.14, *11:30 am* **Perceived bumpiness of 3D-rotating objects are affected by surface reflectance and motion characteristics** Dicle Dovencioglu[1](dicle@bilkent.edu.tr), Maarten Wijntjes[2], Ohad Ben-Shahar[3], Katja Doerschner[1,4]; [1]Department of Psychology & National Magnetic Resonance Research Center, Bilkent University, Ankara, Turkey, [2]Perceptual Intelligence Lab, Industrial Design Engineering, Delft University of Technology, Delft, Netherlands, [3]Computer Science Dept., Ben-Gurion University, Beer-Sheva, Israel, [4]Department of Psychology, Justus-Liebig-University Giessen, Giessen, Germany

The visual system exploits dynamic visual information (optic flow) falling onto the retina when inferring 3D shape. A matte (diffusely-reflecting) moving object conveys visual information about objects motion and its first order shape properties; while the flow from a specular object carries information about the local and global curvature characteristics (second-order shape) and the surface reflectance (Koenderink and van Doorn, 1980). Dovencioglu et al. (2015) showed that the flow of information from matte and specular objects yields differences in perceived local curvature category. Here, we test whether judging 3D curvature magnitude is different for matte and specular objects in dynamic scenes. We asked observers to judge bumpiness of the two consecutive objects in two 2IFC experiments. In Experiment 1, observers compared various test objects to a reference object of specular reflectance and of intermediate bumpiness. In Experiment 2, reference object had matte-textured reflectance. Objects were created by protruding spheres with random sinusoids, and bumpiness level was controlled by the amplitude of the sinusoids. In total, 14 observers completed each experiment (n=28) with bumpiness (5) x material (3: specular, matte, mixed) x motion (3 rotation axes) conditions. By comparing the "proportions judged bumpier" we have observed that in general bumpiness judgements are more difficult for specular objects than for matte. Also, the judgment seemed easier when the reference and test objects had the same surface reflectance. Matte objects were judged less bumpy when rotating around the viewing direction as compared to in-plane rotations regardless of the reference objects' surface reflectance (Exp 2), where specular objects were not susceptible to these rotation axis manipulations (Exp 1). In summary, specular flow can be a robust cue for estimating 3D shape as unlike matte flow it is not affected by different types of object motion.

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52.15, *11:45 am* **Cues Underlying Liquid Constancy** Jan Jaap van Assen[1](janjaap.vanassen@gmail.com), Pascal Barla[2], Roland Fleming[1]; [1]Department of Psychology, Justus-Liebig-University Giessen, [2]Inria - Bordeaux University - IOGS - CNRS

Fluids and other deformable materials have highly mutable shapes, which are visibly influenced by both intrinsic properties (e.g. viscosity) and extrinsic forces (e.g. gravity, object interactions). How do we identify a liquid's intrinsic properties across profound variations in shape caused by extrinsic factors? Previous findings suggest we are surprisingly good at matching viscosity across large variations in shape ("liquid constancy"). Here we ask which visual cues enable us to do this. Somehow the visual system abstracts features that are common to different instances of a liquid, while suppressing large differences in shape caused by extrinsic factors. In this study we tried to specify which geometric features observers use to achieve liquid constancy. We simulated eight variations of pouring liquids with seven different viscosities ('test stimuli'). Each variation was influenced by a different noise force field, like gusts of wind that changed the way the liquid flowed, leading to substantial shape differences over time. Observers adjusted the viscosity of another variation ('match stimulus') until it appeared to be the same material as each test. We tested several time offsets to create volume differences between test and match stimuli. The experiment was performed with static and one-second moving stimuli. We find that observers show a high degree of constancy in matching the viscosity across the different variations. However, volume differences between test and match stimulus, especially with static stimuli, caused large effects of over- and underestimation of viscosity. We then analyzed the 3D shapes of the samples to extract a wide range of shape measurements related to viscosity. We find that a number of cues related to curvatures, periodic movements of the liquids, and the way they spread out predict aspects of the observer's performance, but that humans achieve better constancy than the cues predict.

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52.16, *12:00 pm* **Coupled computations of 3D shape and translucency** Phillip Marlow[1](phillip.marlow@sydney.edu.au), Juno Kim[2], Barton Anderson[1]; [1]Psychology, University of Sydney, [2]Optometry, University of New South Wales

The luminance profiles of opaque and translucent objects exhibit different dependencies on 3D geometry: the shading of Lambertian surfaces exhibits a cosine fall-off as a function of surface orientation relative to the direction of illumination, whereas the light transported through translucent materials declines with the thickness of the object in the direction of illumination. If the visual system relies on these 3D constraints to discriminate opaque and translucent objects, then it should be possible to make a Lambertian object appear translucent (and vice versa) by manipulating its apparent surface orientation and volume. In each experiment, we rendered an image of an object with either Lambertian or translucent material properties, and superimposed sparse random dot fields to generate one of two possible 3D shapes using either motion parallax, binocular disparity, or texture gradients. In Experiment 1, the luminance profile was generated by rendering a Lambertian cone directed at the observer with overhead lighting. Our shape manipulations perceptually transformed the Lambertian cone into a torus, which transformed the appearance into a translucent volume illuminated from within. In Experiment 2, the luminance profile was generated by rendering a back-lit twisted pipe with translucent material properties, and the thickness of the pipe was varied along its length to modulate its brightness. We manipulated the shape to appear as a twisted ribbon, which caused the same gradient to now appear as an opaque matte surface. Although previous work has modulated perceived translucency by manipulating simple image statistics (e.g., luminance contrast and spatial frequency spectra), the experiments reported herein reveal that identical luminance gradients can elicit strikingly different percepts of translucency depending on apparent 3D shape. Together with our previous work on gloss, these results provide strong evidence that the visual system exploits 3D shape constraints to derive material properties from images.

Acknowledgement: Australian Research Council

52.17, *12:15 pm* **Perception of super-fine structures based on image intensity statistics** Masataka Sawayama[1](masa.sawayama@gmail.com), Mikio Shinya[2,3], Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, Japan, [2]Department of Information Science, Toho University, Japan, [3]UEI Research, Japan

We feel that we can recognize the fineness of surface textures with very fine structures, such as human hair, either directly or through photographic images, even when the spatial scale of their individual elements is finer than the spatial resolution limit of the visual system or the physical resolution of the digitized image. Fineness perception of texture might rely not only on the spatial-frequency information of the texture, but also on other diagnostic image features. To investigate this possibility, we first explored to what extent human observers can distinguish differences in super-fine structure. We made a multi-resolution sequence of one-dimensional hair-like random textures through successively applying low-pass filtering and down-sampling. Results of the pairwise comparison between these textures showed that observers could correctly evaluate the fineness of the textures even when the thinnest element was much thinner than the resolution limit of the visual system or that of the digitized image. What happened in the image? According to the central limit theorem, as the fineness of texture increases and the number of elements per pixel increases, the intensity contrast of the texture decreases and the intensity histogram approaches a Gaussian shape. Subsequent experiments revealed that these image features indeed play critical roles in the fineness perception. Specifically, for textures with a unimodal (e.g., Gaussian) distribution, observers perceived the contrast-reduced texture to be finer than the original one. In comparison, for textures with a bimodal distribution, contrast reduction had little effect on fineness perception. These findings suggest that the visual system utilizes the intensity contrast of the texture for estimation of the magnitude of fineness (lower contrast makes the texture look finer) under the condition that the shape of the intensity distribution is consistent with the characteristics of super-fine textures.

Acknowledgement: Supported by: Grant-in-Aid for Scientific Research on Innovative Areas (No. 20396162) from MEXT, Japan.

Perceptual Organization

Tuesday, May 17, 10:45 am - 12:30 pm
Talk Session, Talk Room 2
Moderator: Gary Lupyan

52.21, *10:45 am* **Perceiving Biological Growth and Other Non-Rigid Transformations** Filipp Schmidt[1](filipp.schmidt@psychol.uni-giessen.de), Roland Fleming[1]; [1]Department of Psychology, Justus-Liebig-University Giessen

Morphogenesis—or the origin of complex natural form—has long fascinated researchers from practically every branch of science. Despite dramatic advances in our understanding of how physical and biological processes generate complex shapes like crystals, lungs, or sunflowers, we know practically nothing about how the human mind perceives and understands such processes. Inspired by D'Arcy Thompson's famous work, some researchers suggest the visual system may represent complex shapes and shape transformations as analogous distortions of a perceptual coordinate system. We put this idea to the test. If observers can infer non-rigid transformations, they should be able to estimate how points on or near an object shift in space as a result of the transformation. We showed participants pairs of objects ('before' and 'after' a transformation). On each trial, a probe location was indicated by a dot on or near the 'before' object and participants placed a second dot "at the corresponding location" on or near the 'after' object. Sampling many probe locations allowed us to map out in spatial detail how perceived shape and space were affected by the transformations. We tested four 2D stimulus sets of (1) drawings by D'Arcy Thompson, (2) unfamiliar shapes transformed by global non-rigid transformations, or (3) by local non-rigid transformations (growing 'limbs'), and (4) familiar real-world organisms. Participants' responses were strikingly accurate and mutually consistent for this wide range of shapes and non-rigid transformations. A zero free-parameter model based on matching and interpolating/extrapolating the positions of high-salience contour features predicts the data surprisingly well, suggesting observers infer spatial correspondences relative to key landmarks. Our findings reveal the operation of previously unknown perceptual organization processes that make us remarkably adept at identifying correspondences across complex shape-transforming processes. We suggest this ability is invaluable for many tasks that involve 'making sense' of shape.

Acknowledgement: SFB/TRR 135 German Research Foundation

52.22, *11:00 am* **Human Visual Perception of the 17 Wallpaper-Group Patterns using Timed Trials** yanxi liu[1](yanxi@cse.psu.edu), Jeremy cole[2], david reitter[2]; [1]EECS, College of Engineering, Penn State University, [2]College of Information Sciences and Technology

Most literature on symmetry perception has focused on bilateral reflection symmetry, with some suggesting that it is the only type of symmetry humans can perceive (Wilson&Wilkinson, Vis. Res. 42(5), 2002). Using image-stimuli generated from mathematically well-defined 17 wallpaper groups (Kohler et al., J. Neurosci., in press) and timed trials, we seek to demonstrate that humans can discriminate various symmetries found in 2D wallpaper patterns (Liu, et al Found.&Trends in Comp.Graph.&Vis., 2010). Furthermore, we examine which features play an essential role in wallpaper pattern perception. The features include: reflection, maximum order of rotation, glide reflection, tile shape and subgroup distance, referring to the shortest path between the two wallpaper groups in the group hierarchy. We recruited 106 individuals (Amazon Mechanical Turks) to compare three images (target, probe, probe) and to choose the probe most similar to the target within five seconds. Each participant performed 272 (=17x16) trials. Participants compare among all possible wallpaper group pairs. Every group comparison except one is distinguishable ($p< 0.05$); all are likely distinguishable ($p< 0.10$). After modeling every defining feature of symmetry groups using linear mixed-effects regression (GLMM), we used AIC selection to compare models. Our selected model includs subgroup distance, 3-fold rotation, 4-fold rotation, and the T1 and D1 axes. Even in a model with all other features, subgroup distance is a significant additional predictor ($p< 0.0001$). This distance measure has shown to be a better proxy describing human perceptual processes than individual features. This suggests that the mathematically motivated symmetry group hierarchy may be a valid model of pattern perception.

52.23, *11:15 am* **The role of contour length, convex hull, and density in early versus late visual number encoding** Darko Odic[1](darko.odic@psych.ubc.ca); [1]Department of Psychology, University of British Columbia

When identifying the number of objects in a visual scene, observers frequently mistake patches of dots that are denser, larger, or longer as more numerous. Such "incongruency effects" have supported claims that the visual system doesn't represent number directly, but instead encodes number by combining several non-numeric features, including density, convex hull, and contour length (e.g., Gebuis et al., 2011; Dakin et al., 2011). However, incongruency effects may instead be a product of a response conflict between number and other dimensions, much like in a Stroop task. To test whether incongruency emerges due to encoding or response conflict, participants completed two tasks: a Discrimination task, indicating whether more of the dots are blue or yellow, and an Estimation task, estimating the number of blue or yellow dots. Non-numeric cues, including contour length, convex hull, and density, were made incongruent with number (Fig. 2). Importantly, while the Discrimination task creates a response conflict – the "blue" and "yellow" response for number competes with the response for the non-numeric dimensions – the Estimation task eliminates it, as participants are forced to use number words. In Experiment 1, dots were arranged along lines, inducing a conflict between number and contour length. While we observed the incongruency effect in the Discrimination task – dots along the longer line were identified as more numerous – participants showed no bias in the Estimation task (Fig. 2). In Experiment 2, we replicate these findings when inducing an incongruency between number and convex hull. Finally, in Experiment 3, we found that density – unlike contour length and convex hull – produces an incongruency in both Discrimination and Estimation (Fig. 3). These results provide a method for testing encoding vs. response conflict components in number encoding, and show that only some dimensions affect number when response conflicts are controlled for.

52.24, *11:30 am* **Face processing interferes with word identification during rapid serial visual presentation** Amanda Robinson[1](arobins1@andrew.cmu.edu), David Plaut[1], Marlene Behrmann[1]; [1]Department of Psychology, Carnegie Mellon University

Words and faces have vastly different visual properties but increasing evidence suggests that word and face processing involve overlapping distributed networks. For instance, fMRI studies have shown overlapping activity for face and word processing in the fusiform gyrus despite well-characterized lateralization of these object types in the left and right hemispheres, respectively. Furthermore, individuals with prosopagnosia and dyslexia exhibit deficits in both face and word perception. To investigate whether overlapping neural mechanisms of face and word processing can manifest in perceptual interference in healthy individuals, we presented images using rapid serial visual presentations at 10Hz. In three experiments, participants (N = 42, 20, 20) discriminated two face, word and glasses targets (T1 and T2) embedded in the image stream. As expected, second target discrimination was impaired when it followed the first target by 200-300ms relative to longer inter-target intervals, the so-called "attentional blink". Interestingly, T2 identification was much lower at short inter-target intervals when a face target was followed by a word compared with glasses-word and word-word combinations, indicating that face processing interfered with word perception. Faces did not cause a larger "blink" for the other stimulus types. The opposite effect was not observed; that is, a word T1 did not impair face T2 discrimination more than the other object types. The same pattern of results was observed for different target identification tasks and relative image sizes. EEG results indicated face T1 processing impaired word T2 processing at the N170 component. Taken together, the results suggest face processing specifically interferes with word processing, providing evidence for overlapping neural mechanisms of these two object types. Furthermore, asymmetrical face-word interference points to a difference in the temporal aspects of face and word processing such that faces processing interferes with word perception but not vice versa.

52.25, *11:45 am* **Objective effects of knowledge on visual perception** Gary Lupyan[1](lupyan@wisc.edu); [1]University of Wisconsin-Madison

Imagine you are having your eyesight tested. The optometrist asks you to look at a line on a Snellen chart. The letters look a bit blurry, but you can make out the first as "R." To what extent does your knowledge of what something looks like (in this case, the form of the letter "R") actually help you see it? This stunningly simple question is surprisingly difficult to answer. If people report that they see familiar objects more clearly than less familiar ones, they may be biased to report familiar objects as being easier to see. If people turn out to be better at recognizing more familiar objects, perhaps they are just better at guessing the identity of familiar objects (e.g., guessing a blurry R to be an "R"). To avoid these pitfalls, we used a novel task that tested people's ability to detect contrast changes (blurring and sharpening) of marginally-legible letter strings. Across four experiments (N=90), we measured the difference in people's ability to detect these changes in (a) meaningful vs. scrambled sentences and words (Exps. 1-2), (b) high-frequency vs. low-frequency words (Exp. 3), and (c) the effect of being told what one was looking at (Exp. 4). In all cases, prior knowledge overwhelmingly increased people's judgments of legibility. But in addition, knowledge improved objective performance in detecting visual changes. For example, people's detection of sharpening in real sentences was 80% compared to 70% when viewing scrambled sentences containing all the same letters ($z=4.2$, $p< .0001$). Performance was also better for more frequent relative to less frequent words, and when people heard the word prior to seeing it. This novel demonstration of knowledge affecting on-line visual perception provides strong counter-evidence to recent claims that visual perception is not modulated by prior knowledge and expectations.

Acknowledgement: NSF BCS#1331293 to GL. Jonathan Lang helped with project.

52.26, *12:00 pm* **Facilitatory lateral interactions in patients with age-related macular degeneration** Marcello Maniglia[1,2](marcello.maniglia@gmail.com), Benoit Cottereau[1,2], Vincent Soler[3], Yves Trotter[1,2]; [1]Université de Toulouse-UPS, Centre de Recherche Cerveau et Cognition, Toulouse, France, [2]Centre National de la Recherche Scientifique, Toulouse Cedex, France, [3]Unité de rétine, consultation d'ophtalmologie, hôpital Pierre-Paul-Riquet, CHU de Toulouse, place Baylac, 31059 Toulouse cedex, France

Age-related macular degeneration (AMD) is a visual pathology that affects the central part of the retina, the macula. It represents the main cause of visual disease and blindness in elderly population. AMD usually leads to the spontaneous development of a preferential retinal locus (PRL) in the spared retina, adopted as a new eccentric fixation point. Because of possible spontaneous plasticity within the cortical regions formerly responding to central vision, it was suggested that peripheral vision, specifically around the PRL, might be different in AMD patients respect to normal subjects. In this study, we used collinear facilitation to test this hypothesis. Five AMD patients (mean age: 72, mean PRL eccentricity: 8°) had to detect the appearance of a Gabor patch (1 cpd, $\sigma = 1°$) in their PRL. This patch was co-aligned with a pair of Gabor flankers placed at distances varying between 3° and 8°. A group of age-matched controls was tested at the same eccentricity as the patients' PRLs. The first result of our analysis is that collinear facilitation is consistently present in AMD patients, and emerges at the same target-to-flankers distances as for the control subjects. At a first glance, cortical reorganization would appear marginal in AMD patients; however, we found weaker inhibition at short target-to-flankers distances (mostly 3°) and linearly increasing facilitation for the larger target-to-flankers distances (6° and 8°), hinting toward an overall larger range of facilitation in AMD patients. This pattern of response is a trademark of perceptual learning effects in normal population. Our results therefore demonstrate that AMD patients underwent at least a partial reorganization, possibly induced by spontaneous plasticity. Further studies will evaluate whether perceptual learning can boost neural plasticity in AMD patients.

52.27, *12:15 pm* **Visual shape completion deficits arise in first-episode and chronic schizophrenia, but are less severe in bipolar disorder: Evidence for a novel behavioral biomarker** Brian Keane[1,2,3](brian.keane@gmail.com), Danielle Paterno[2], Sabine Kastner[4,5], Steven Silverstein[1,2]; [1]Department of Psychiatry, Robert Wood Johnson Medical School, Rutgers University, [2]University Behavioral Health Care, Rutgers University, [3]Center for Cognitive Science, Rutgers University, [4]Princeton Neuroscience Institute, Princeton University, [5]Department of Psychology, Princeton University

Background. Behavioral and electrophysiological studies indicate that people with chronic schizophrenia poorly integrate elements to form visually completed shapes. Is this deficit specific to schizophrenia? If so, may it be found as early as the first psychotic episode? Affirmative answers would potentially validate the impairment as an illness biomarker. Methods. To address the issue, we report data from two separate studies—the first comparing chronic schizophrenia (SZ), healthy control, and bipolar disorder (BD) patients (Study 1); the other comparing SZ, healthy control, and first episode (FE) psychosis patients (Study 2). In each case, subjects judged whether four pac-men formed a fat or thin illusory square (illusory condition) or whether four downward-pointing pac-men were individually rotated left or right (fragmented condition). Task difficulty depended on pac-man rotational magnitude, with larger rotations making the response alternatives easier to distinguish. An adaptive staircase determined threshold—the amount of rotation needed for 80% discrimination accuracy. Visual shape completion ability was measured as the extent to which performance in the illusory condition exceeded that of the fragmented. Results. In Study 1, shape completion was worse in SZ patients than in BD patients ($p< .05$) or controls ($p< .001$); and it was marginally worse in BD patients than in controls ($p=.07$). In Study 2, completion was better in controls than in FEs and SZs ($ps< .01$), but the latter groups were indistinguishable ($p>.5$). Interestingly, in each study, the schizophrenia patients who most clearly demonstrated completion deficits were those who suffered from higher levels of conceptual disorganization, a clinical symptom that impedes clear thinking and verbal communication. Conclusions. These results suggest that poor visual shape completion furnishes a biomarker for schizophrenia: the deficit arises by the first psychotic episode, is more pronounced than in bipolar disorder, and may be most apparent in a conceptually disorganized patient subtype.

Acknowledgement: F32MH094102 to BPK

Tuesday Morning Posters

Spatial Vision: Models

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

53.3001 **Visual discrimination is a two-stage process** Peng Sun[1](peng.sun@nyu.edu), Michael Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

The difficulty of a visual discrimination task depends on stimulus strength (e.g., contrast C) and stimulus value (e.g., Gabor orientation θ in an orientation-discrimination task relative to vertical). Signal detection theory predicts poor performance when the expected likelihood function of the decision variable has high variance (for small C) or has a mean close to the decision criterion (small θ). How does the decision variable evolve over time and what are the consequences for reaction-time (RT) tasks? We consider two neural population-code models. (1) Drift-diffusion model (DDM): Momentary discrimination evidence accumulates until a decision bound is reached (a single-stage decision process). Predicted RT(C,θ) decreases with increasing C and θ but with an interaction: RT as a function of C is steeper for lower values of θ. (2) Two-stage model (TSM): Stage 1: Neural responses are accumulated until a threshold reliability of estimated orientation is reached (or until at least one neuron has fired a criterion number of spikes). Stage 2: the estimate is compared to a decision criterion, a process that takes longer for more difficult discriminations. Stage 1's duration is a function of C alone; stage 2's duration is a function of θ alone (i.e., no interaction). We report three discrimination experiments: (1) location discrimination of a Gaussian blob (RT=f(x,C)), (2) orientation discrimination of a Gabor (RT=f(θ,C)), and (3) direction discrimination of a random-dot kinematogram with coherence=C (RT=f(θ,C)). In all three cases, RTs, when plotted against C for different values of θ, are largely parallel, supporting TSM over DDM. TSM, unlike DDM, also predicts that in a cued-response task, RT will decrease with increasing response-cue delay. We measured RT as a function of response-cue delay in the motion-discrimination task. RT decreased with increasing cue delay. Overall, our results favor the two-stage model of discrimination over the drift-diffusion model.

Acknowledgement: NSF BCS-1430262

53.3002 **Contrast sensitivity: Measuring late internal noise across spatial frequencies** Daphne Silvestre[1](daphne.silvestre@inserm.fr), Angelo Arleo[1], Remy Allard[1]; [1]Sorbonne Universités, UPMC Univ Paris 06, INSERM, CNRS, Institut de la Vision, Paris, France.

The dominant source of internal noise limiting contrast sensitivity depends on various parameters of the stimulus. For instance, early photon noise is the dominant source of internal noise at high spatial frequencies and low luminance intensities, whereas late cortical noise is the dominant source of internal noise at low spatial frequencies and high luminance intensities. This shift in the dominant source of internal noise is due to the fact that photon noise is inversely proportional to luminance intensity and independent of spatial frequency, whereas late cortical noise drops with spatial frequency and is independent of luminance intensity. Cortical noise has been measured only at low spatial frequencies and was found to drop linearly (Pelli, 1990). The purpose of our study was to measure the late internal noise (independent of luminance) over a wide range of spatial frequencies. Given that early noise decreases with luminance intensity, late noise is the limiting noise source at very high luminance intensities even for high spatial frequencies. The internal equivalent noise and the calculation efficiency were measured over a wide range of spatial frequencies (0.25 to 16 cpd) and luminance intensities (16 to 16261 Td). Calculation efficiency was found to be independent of spatial frequency and luminance intensity. At high luminance intensities, internal equivalent noise was independent of luminance intensity at all spatial frequencies tested, which implies that the internal noise limiting contrast sensitivity was not early photon noise but late noise. This late noise was found to drop non-linearly with spatial frequency. The drop was less steep at high spatial frequencies compared to the low spatial frequencies. Further studies are required to investigate the cause of this nonlinear relation between late noise and spatial frequency.

Acknowledgement: This research was supported by ANR – Essilor SilverSight Chair

53.3003 **Emulating and predicting physiological results of neurons in the primary visual cortex (V1) based on the divisive normalization model** Tadamasa Sawada[1], Alexander Petrov[2]; [1]School of Psychology, Higher School of Economics, [2]Department of Psychology, Ohio State University

The response properties of simple and complex cells in V1 have been studied physiologically, and many models have been proposed. Note that a model must have adjustable parameters and be flexible enough to capture the diversity of response profiles of V1 neurons. On the other hand, the model must be rigid enough to be falsifiable. Using a combination of simulation experiments and mathematical analyses, we show how to satisfy these complementary conditions for the popular divisive normalization model (Heeger, 1992, Vis. Neurosci.; Carandini & Heeger, 2012, Nature Reviews Neurosci) for V1 neurons. A Matlab implementation of the model that can take static grayscale images as inputs was applied systematically to a battery of visual stimuli used in dozens of published physiological studies. We found that, with a small set of parameters consistent with empirical measurements, the model can account for over 25 phenomena in single-cell recordings of simple and complex cells in V1. Mathematical analysis showed that a parameter representing the maintained discharge (baseline firing rate) of the model neuron plays a critical role in three physiological phenomena: (A) the existence of inhibitory regions in the receptive fields of simple cells in V1, (B) the super-saturation effect in the contrast sensitivity curves, and (C) the narrowing/widening of the spatial-frequency tuning curves when the stimulus contrast decreases. Importantly, the association with a single parameter makes these three phenomena interdependent. This predicts that simple cells in V1 can be categorized in the following two mutually exclusive types: One type of cell shows phenomena A, B, and widening (C); the other shows not-A, not-B, and narrowing (C). This prediction of interdependence is potentially falsifiable. The simulation experiments and mathematical analyses show that the model satisfies the complementary desiderata of flexibility and rigidity.

Acknowledgement: NIH Research Grant R21 EY022745-01

53.3004 **Revealing the hidden responses of a sparse coding network** Kedarnath Vilankar[1](kpv9@cornell.edu), James Golden[2], David Field[1]; [1]Cornell University, [2]Stanford University

Traditionally, in biological and artificial neural networks, a neuron's response is represented as a two-dimensional feature map (or receptive field). This receptive field typically represents the stimulus for which the neuron is most responsive. For sparse codes applied to natural scenes, the receptive fields often resemble those of V1 simple cells. Highly overcomplete sparse codes (e.g., 10 times overcomplete) often reveal a wider variety of receptive fields. This variety is usually the most noted aspect of these overcomplete codes. However, the response properties of the neurons in these codes are often quite non-linear. Here, we provide a method of visualizing these non-linearities in terms of the curvature in the iso-response surfaces. We measured the iso-response surfaces of artificial neurons in a sparse coding network in response to natural scenes. We find that as the code becomes more overcomplete, the magnitude of the non-linearity increases (the iso-response surfaces become more curved). This curvature in iso-response contours also describes the nonlinearities observed in V1 (such as end-stopping, cross-orientation inhibition, contrast gain control, etc.). Although it has been argued the precise form of the cost function does not have a large effect on the family of receptive fields produced, we show that this does have a significant effect on the non-linear responses (the precise form of curvature). We discuss these results in terms of the magnitude of non-linearities in V1 neurons and the theorized degree of overcompleteness in the primate visual system. We also show that both selectivity and invariance can be described in terms of this curvature.

Acknowledgement: Google Faculty Research award

53.3005 **An Image-Based Model for Early Visual Processing** Heiko Schütt[1,3](heiko.schuett@uni-tuebingen.de), Felix Wichmann[1,2]; [1]Neural Information Processing Group, Faculty of Science, and Bernstein Center for Computational Neuroscience Tübingen, University of Tübingen, Germany, [2]Empirical Inference Department, Max Planck Institute for Intelligent Systems, Tübingen, Germany, [3]Graduate Training Center of Neuroscience, University of Tübingen

See page 3 for Abstract Numbering System

Early spatial vision was explored extensively over several decades in many psychophysical detection and discrimination experiments, and thus a large body of data is available. Goris et al. (2013; Psych. Rev.) integrated this psychophysical literature and proposed a model based on maximum-likelihood decoding of a neurophysiologically inspired population of model neurons. Their neural population model (NPM) is able to predict several data sets simultaneously, using a single set of parameters. However, the NPM is only one-dimensional, operating on the activity of abstract spatial frequency channels. Thus it cannot be applied to arbitrary images as a generic front-end to explore the influence of early visual processing on mid- or high-level vision. Bradley et. al. (2014; JoV), on the other hand, presented a model operating on images. Their model is thus able to make predictions for arbitrary images. However, compared to the NPM, their model lacks in nonlinear processing, which is replaced by an effective masking contrast depending on the detection target. Thus while Bradley et al. fit a range of detection data they do not fit nonlinear aspects of early vision like the dipper function. Here we combine both approaches and present a model which includes nonlinear processing and operates on images. In addition, the model applies optical degradation and retinal processing to the image before it is passed to a spatial frequency and orientation decomposition followed by divisive inhibition. For the optical transfer function of the eye and the distribution of retinal midget ganglion cells we use the approximations of Watson (2013, 2014; JoV). We tested the predictions of our model against a broad range of early psychophysical literature and found it predicts some hallmarks of early visual processing like the contrast sensitivity function under different temporal conditions and the dipper function for contrast discrimination.

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53.3006 **A model of V1 metamer can explain perceived deformation of a static object induced by light projection.** Taiki Fukiage[1], Takahiro Kawabe[1], Shin'ya Nishida[1]; [1]NTT Communication Science Laboratories

Models of visual metamers have played a great role in development of display technologies. Starting from the invention of color displays based on human trichromacy, models of V1 have also successfully been applied to image processings and image quality assessments (e.g., Daly, 1992). Here, we show that such an approach can be effective to an emerging display technology such as projection mapping. In this study, we worked on "Deformation Lamps," a light projection technique developed by Kawabe et al. (2015), which adds dynamic impressions to a real static object (e.g., a picture of flames fluttering in the dark). The technique superimposes a dynamic sequence of grayscale patterns onto arbitrary (colorful) objects such that the combination of the dynamic signal and the original static information effectively drives motion mechanisms in the brain. However, if the spatial and/or contrast deviation between the superimposed pattern and the static information exceeds a certain limit, the visual system cannot resolve the inconsistency between the dynamic and the static information. The aim of this study was thus to establish a perceptually equivalent representation that can predict the limit in a given projection setting. In the experiment, we projected dynamic patterns to 10 different natural images while varying the deformation size and the contrast of the projection patterns as independent variables. The participants were asked to judge whether they perceived a natural impression of deformation of a static image or not. Under the conditions in which the natural impressions were obtained, the participants also reported the perceived size of the deformation by adjusting the deformation size of the test movie sequence. As a result, we found that a model of the response properties in V1 neurons can explain the perceived deformation sizes as well as the subjective inconsistency (measured as proportion of "unnatural" responses).

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53.3007 **Estimating and comparing models of neural encoding and decoding using psychophysical experiments** Christopher DiMattina[1](cdimattina@fgcu.edu); [1]Computational Perception Laboratory, Department of Psychology, Florida Gulf Coast University

Most psychometric models are defined in terms of free parameters which lack a clear neurobiological interpretation. This limits the ability of most psychophysical experiments to speak directly to issues of neural encoding mechanisms, or questions of how neural responses are decoded to guide behavior. In this study, we introduce a general computational methodology for defining a psychometric model in terms of an assumed underlying neural encoding model and neural decoding model. We demonstrate that this methodology can be used to define a psychometric model whose free parameters are those defining the neural encoding and decoding models, and which does not depend on unobserved neuronal responses. We apply our method to the problem of estimating the parameters of the neural contrast gain function for a hypothetical population of orientation-tuned V1 neurons. By fitting a psychometric function derived using our method to psychophysical data obtained from an orientation-discrimination experiment, we accurately estimate neural contrast gain function parameters (half-saturation, shape) in the known physiological range. Furthermore, we demonstrate that it is possible to use psychophysical data to distinguish between two qualitatively similar (but quantitatively different) candidate models of neural contrast gain. We show that this process of model comparison is greatly aided by adaptive stimulus generation methods, where a stimulus optimized for discriminating competing models is generated during the course of the experimental session based on the best fit of each model to data collected earlier in the session. We suggest that our methodology may in many cases permit psychophysical experiments to more directly inform and guide neurophysiological investigations.

53.3008 **Some observations on the psychophysics of Deep Neural Networks** David Janssen[1,2](janssen.dhj@gmail.com), Heiko Schuett[1,2], Felix Wichmann[1,3,4]; [1]Neural Information Processing Group, Faculty of Science, University of Tuebingen, Germany, [2]Graduate Training Centre of Neuroscience, University of Tuebingen, Germany, [3]Max Planck Institute for Intelligent Systems, Empirical Inference Department, Tuebingen, Germany, [4]Bernstein Center for Computational Neuroscience Tuebingen, Germany

Deep convolutional neural networks (DNNs) are currently very popular, drawing interest for their high performance on object classification tasks. Additionally, they are being examined for purported parallels between their hierarchical features and those found in systems of biological vision (e.g. Yamins etal., 2014). Human vision has been studied extensively by psychophysics using simple grating stimuli, and many experimental results can be accommodated within a model where linear filters are followed by point-wise non-linearities as well as non-linear interactions between filters (Goris et al., 2013). However, two of the most striking failures of current spatial vision models are their inability to account for the contrast-modulation experiments by Henning et al. (1975) and the plaid-masking experiments by Derrington and Henning (1989). Googlenet and Alexnet are two DNNs performing well on object recognition. We ran contrast-modulated and plaid-masking stimuli through the networks and extracted the layer activations. Since these networks are fully deterministic, we designed an optimal linear decoder around the assumption of late, zero-mean additive noise, where the variance of the noise was calibrated to match human performance on contrast detection experiments. Unlike human observers, neither Alexnet nor Googlenet show any trace in any of their layers of masking by contrast-modulated gratings. Worse still, adding the contrast-modulated mask strongly facilitated detection. Using plaid-masks, Googlenet again showed strong facilitation. Alexnet, on the other hand, shows plaid-masking effects at least qualitatively similar to those found in human observers. However, this was only true for the last layers, the "object" layers, not the early layers. Strong claims that DNNs mirror the human visual system appear premature. Not only do the DNNs fail to show the masking effects found in human observers, different DNNs were found to behave wildly differently to simple stimuli.

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53.3009 **Brightness Illusions and the Benary Cross: A Modified ODOG Explanation** Aaron Clarke[1](aaron.clarke@bilkent.edu.tr), Mark Vergeer[2]; [1]Departments of Psychology & Neuroscience, Bilkent University, Ankara, Turkey, [2]Brain and Cognition, University of Leuven, Leuven, Belgium

In the Benary cross illusion two gray triangles are perceived on a black cross against a white background. Interestingly, the placement along the cross and the orientation of the gray triangles crucially determines their perceived brightness, even though both the triangles, and the local contrasts at their borders are identical. This phenomenon has heretofore resisted mechanistic explanation. Local, isotropic filtering models, which have enjoyed considerable success in predicting other brightness illusions such as White's effect or the Adelson checkerboard, fail to correctly predict psychophysical data obtained with this stimulus in different orientations.

Tuesday AM

Here we present a modified version of Blakeslee and McCourt's ODOG model that succeeds in explaining the Benary cross illusion and modifications of it. A key insight embodied in our modified model is that oriented filter outputs should be weighted according to psychophysically determined orientation sensitivity (contrary to the original ODOG formulation, which weighted oriented responses according to the space-averaged RMS contrast level). Not only does our model explain the psychophysical data from the Benary cross illusion, but it also retains the explanatory power of the original Blakeslee and McCourt model, thus providing a valuable formulation for predicting how we perceive brightness in the world.

53.3010 **Psychophysical evaluation of a novel visual noise metric for renderings** Thomas Maier[1](thomas.maier@nextlimit.com), Fran González García[1], Roland Fleming[2]; [1]Maxwell Render, Next Limit, [2]Department of Psychology, Justus-Liebig-University Giessen

Almost all photorealistic rendering algorithms involve stochastic sampling, which often leads to visually objectionable noise in the image. Avoiding such noise remains one of the most important challenges for photorealistic image synthesis. The nature and quantity of noise depends on the sampling algorithm and number of samples. However, the noise's visibility also depends heavily on the human visual system (contrast sensitivity, masking, etc.). We have developed a novel metric for identifying noise in hyperspectral renderings. Here we used psychophysical noise detection tasks to (1) test how well the metric predicts noise visibility in complex scenes, and (2) determine parameter values that yield acceptable images for a wide range of conditions. The findings not only provide perceptually-based parameter values for detecting noise artifacts with our algorithm, but also yield novel insights into how the visual system distinguishes erroneous artifacts from genuine spatial variations of colour and intensity in the scene. The noise metric uses the information theoretic quantity 'Jensen-Shannon divergence (JSD)', to measure similarities between the spectra of different pixels. During rendering, a threshold parameter determines how much variation in the wavelength distribution is deemed acceptable, at which point no further samples are acquired for that pixel. We created a wide range of scenes containing several textured objects in rooms with spatial variations of lighting and surface material. For each scene, we varied the threshold parameter, yielding a series of images with varying degrees of noise. In a 2AFC task participants identified which of two images matched a noise-free reference rendering. Whole images and patches were tested. Our findings verify that the JSD-based metric correctly predicts human noise detection for rendered scenes and image patches, and identify parameter values that yield acceptable results. We discuss the consequences of this metric for theories of human visual noise detection.

Acknowledgement: EU Marie Curie ITN PRISM

53.3011 **Measuring the Contrast Sensitivity Function in just three clicks** Jessica Tardif[1](jessica.tardif.1@umontreal.ca), Marcus Watson[2], Deborah Giaschi[2], Frédéric Gosselin[1]; [1]University of Montreal, [2]University of British Columbia

The Contrast Sensitivity Function (CSF) is altered in many visual disorders. However, measurement of the CSF is often overlooked for lack of time (e.g. Pelli & Bex, 2013). Here, we introduce an ultra-fast psychophysical method to measure the CSF. Observers were asked to fit a truncated log-parabola (Lesmes, et al., 2010) to an on-screen rendition of the Campbell-Robson chart (Campbell & Robson, 1968; Pelli, 1987) by adjusting its four parameters in just three clicks. The chart measured 14.4×8.1 deg of visual angle. Spatial frequencies spanned 0.16 to 40 cycles per degree (cpd) from left to right, and contrasts ranged from 0.005 to 0.25 from top to bottom. Participants first clicked on the perceived peak of the CSF, providing fmax and ymax estimates. Second, they adjusted the full-width at half-maximum of the right half of a log-parabola by moving the mouse sideways, providing a β estimate. Finally, participants adjusted the height of the truncation parameter (δ) by moving the mouse vertically. Seventy-eight participants (age: 7-36) completed three runs. In addition, an orientation discrimination task (horizontal/vertical) was used with the same participants to validate the ultra-fast CSF method. Gabor patches measured 2 degrees of visual angle and ranged from 0.5 to 30 cpd in seven logarithmic steps. A threshold for each spatial frequency was measured in 336 trials with the QUEST method (Watson & Pelli, 1983). We obtained an overall root-mean-square error of 4.53 dB between the QUEST thresholds and the ultra-fast thresholds, which compares favorably to other methods, such as qCSF (Lesmes et al., 2010). The ultra-fast CSF method still needs to be improved, but it shows promise for use with children and adults with typical vision. Its use with patient populations will have to be validated.

53.3012 **Testing a novel tool for vision experiments over the internet** Kenchi Hosokawa[1](hosokawa.kenchi@gmail.com), Kazushi Maruya[1], Shi'nya Nishida[1]; [1]NTT Corporation

For precise stimulus control, psychophysical experiments have been usually carried out with a high-performance graphics system set up in a darkroom. The critical limitation of this conventional setup is the difficulty in increasing the data size. To collect psychophysical data with a reasonable quality from a much larger sample of observers, we are developing new software for vision experiments over the internet. This software is based on HTML5 and WebGL implemented in the latest browsers. Editing, distribution, execution and data collection are all operated over web pages browsed by personal computers or tablets. We assessed precision and accuracy of this software with various web browsers running on Windows, Mac OS X, iOS and Android. Temporal precision was measured by sampling luminance of 30 Hz flicker with photodiode. Our software shows good temporal performances under Google Chrome and Internet Explorer regardless of OS, while the timing error increased under the other browsers. Since gamma correction table on the video cards are not operable from browsers, we implemented spatiotemporal dither to linearize the image intensity. Pixel-to-pixel drawing is achieved by complying OpenGL specification. We added a function to keep pixel-to-pixel drawing under pixel-magnifying devices such as Apple retina display. Finally we tested whether basic psychophysical experiments could be replicated with this software. We found, for example, the contrast sensitivity function measured with our new software agreed well with the results reported by past studies and those we collected with a conventional experimental setup. These results certificate that this software is platform-independent tool having a capacity to run many traditional darkroom experiments anywhere and anytime over the internet and/or with tablet devices.

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Perception and Action: Timing, interception and online control

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

53.3013 **Increased variability in a temporal-coincidence task after adaptation to delays: a possible explanation** Elisabeth Knelange[1](l.knelange@ub.edu), Joan López-Moliner[1]; [1]Departament de Psicologia Bàsica Universitat de Barcelona

People are able to predict the sensory consequences of their motor commands, such that they can compensate for delays in sensorimotor loops. It has been shown that integrating different sources of sensory information improves the precision of the prediction, but we lose precision when we adapt to sensory delays. There are two possible explanations for this: 1) The temporal conflict of the sensory modalities results in the loss of integration; 2) The delay forces people to rely more on the prediction of the consequence. To explore these options, subjects had to anticipate conflicting sensory information in a temporal-coincidence task. A target on a screen moved from left to right towards a reference line (at different speeds/distances). Subjects were instructed to press a button when the target came in contact with the line. As a consequence of the press, the target disappeared (visual feedback) and a sound was presented (auditory feedback). In the following conditions, either the visual consequence (VD condition), auditory consequence (AD condition) or both were delayed (VAD condition). Every condition consisted of a block of incremental delay (135 trials, 1ms/trial) followed by a block of fixed delay (135ms). The results show that the adaptation to delay is present in the conditions were the visual consequence is delayed (VD, VAD), but not when only the auditory consequence is delayed (AD). This is consistent with subjects using only the visual feedback to evaluate the success on the task. As expected, subjects show a decreased precision when adapting, compared to the conditions without adaptation. Importantly, the precision is not better in the VAD condition, suggesting that the accessory beep is not integrated. We propose that the increased variability is due to subjects having to rely on the prediction of the consequence whose uncertainty increases with the delay.

Acknowledgement: project PACE H2020-MSCA-ITN-2014 Ref. 642961

53.3014 **Neural Correlates of Adaptation to Visuo-Motor Delays** Clara Cámara[1](clara.camara@ub.edu), Josep Marco-Pallarés[1], Joan López-Moliner[1]; [1]Universitat de Barcelona

Tuesday AM

When exposed to sensorimotor visual delays people soon learn to control the cursor to intercept a target. This suggests that adaptation to delays in an interception task strongly depends on the coordination of the motor action with the visual information of the delayed cursor. Often people do not generalize to other tasks (de la Malla et al. 2014) implying that proprioception is not temporally realigned with vision. We explore the neural basis of this adaptation by building on the idea that oscillatory coupling between visual and somatosensory areas underpins the interaction between them and should be observed in baselines conditions. We hypothesize that this synchronization will be reduced after adaptation if realignment does not happen. In order to test this hypothesis we measured EEG (32 channels) while subjects performed an interception task. The behavioral experiment was divided in 4 phases: full vision (FV), no vision (NV), adaptation (A), and NV. In the adaptation phase, we incrementally increased (1msec/trial) the temporal difference between the hand and the cursor movements. In the analysis we further divided the adaptation phase in early adaptation (EA) and late adaptation (LA). Since the feedback of the experiment was visual, we focused the analysis on the alpha band (8-12 Hz). Under FV, all subjects (irrespective of the adaptation strength) presented a synchronic activity between occipital and centro-lateral electrodes. However, the synchronization changed depending on the level adaptation to the visual delay. Participants with good adaptation presented less synchronization at EA than FV, and no synchronization at LA. The synchronization remained after adaptation for participants with little adaptation. These results suggest that adaptation to visuomotor delays does not require strong interactions between visual an proprioceptive areas and would be consistent with an absence of temporal realignment between these areas.

Acknowledgement: 2014 SGR0079 and PSI2013-41568-P

53.3015 Internal timing adjustments in interception revealed by Kalman filtering and diffusion processes

Joan López-Moliner[1](j.lopezmoliner@ub.edu), Matthias Keil[1]; [1]Universitat de Barcelona

When we repeatedly hit a moving target, we can make adjustments based on prior errors (e.g. start moving later if we were early previously). Different types of random noise (e.g. in the movement initiation and motor execution) contribute to this error. Therefore, the internal programming of next movement's adjustment should discount part of the error. To test this hypothesis subjects had to intercept a target at a designated interceptive area (no spatial error) and analyzed the dependence of the time of action initiation (TAI) on the previous TAI and temporal error. We addressed the problem of estimating the internal temporal adjustments by fitting a Kalman filter (KF) to the time series based on the TAI. The estimated transition of hidden states in the KF identifies the internal adjustments with a process noise (w) and the observed TAI is the measurement that includes the propagated motor noise. The previous temporal error served as control input whose coefficient (B) provides an estimate of the fraction of the observed error that is effectively used to determine the new hidden state. For each subject and session we estimated w and B as free parameters of the KF. On average, B was 0.15: the internal adjustments of the TAI accounted for the 15% of the total temporal error in the previous trial. The process noise (w) was between 6 and 10 ms and corresponded to 26% of the TAI variability. Finally we simulated the internal adjustments as corresponding variations in the initial state of a diffusion process and the arrival times as the TAI. Variations of 15% in the initial state led to adjustments in TAI that corresponded to full corrections of the temporal error as observed in the experiment. The internal timing of timed actions seems then tuned to propagated motor noise.

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53.3016 Humans integrate both speed and elapsed time cues for object interception

Chia-Jung Chang[1](chiajung@mit.edu), Mehrdad Jazayeri[1,2]; [1]Department of Brain and Cognitive Science, MIT, [2]McGovern Institute for Brain Research, MIT

To intercept a moving object, the brain must compute a reliable estimate of time-to-contact (TTC), which can be inferred from measurements of speed, elapsed time and position. Since these variables are physically interrelated, it is challenging to tease apart the sensory cues that guide this behavior. Previous studies have shown that humans rely on speed estimation and distance to compute TTC. However, given the brain's capacity to measure interval timing independent of speed, it is conceivable that humans utilize an estimate of elapsed time to further improve their performance. To test this possibility, we asked subjects to press a button when an initially visible moving object would arrive at a designated target location behind an occluder. We found that their TTC estimation had the lowest mean squared error when the visible and occluded regions had the same length and duration, suggesting that subjects might additionally use a measure of elapsed time to compute TTC. To test the hypothesis more directly, we modified the object interception task to dissociate speed and timing information. The speed cue was provided by a brief visible region at the beginning of the trial, whereas the timing cue was provided by a flash bisecting the actual TTC. When the cues were presented separately, a Bayesian model integrating prior distribution with relevant sensory measurement accounted for performance. When both cues were available, performance improved beyond what could be attributed to either time or speed measurement alone, suggesting that subjects combined both speed (from the visible region) and elapsed time (from the flash) cues to estimate TTC. An additional cue conflict paradigm further substantiated the evidence that subjects integrate both speed and elapsed time to optimize their performance. These findings suggest that the brain integrates signals associated with timing and speed to control motor responses during object interception.

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53.3017 Eye movement and steering control in locomotor interception

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It has been shown that in locomotor tasks people actively direct their gaze to locations in an environment at the right time so as to support locomotor control (Land, et al., 1994; Wilkie, et al., 2008). When walking to intercept a moving target, people appear to maintain the target at a constant bearing angle with respect to an allocentric reference axis (Chardenon, et al., 2002; Fajen, et al., 2004, 2007; Lenoir, et al., 1999). Therefore the question arises how humans direct their gaze during steering for interception. To examine it, participants (N=18) drove a car to intercept a moving target in a virtual environment. The environment was presented stereoscopically in a head mounted display. While the car moved at a constant speed (7 m/s), participants controlled its moving direction using a steering wheel. The target (40m distant) moved to the left or right at a constant speed (4, 5, or 6 m/s) in a trial. In half the trials, the target remained visible through a trial; in the other half, it suddenly disappeared 2.5 s after it appeared. When intercepting the visible target, participants initially made saccades to the target, and then smoothly pursued it until interception. The bearing angle towards the target systematically changed during interception. Instead, participants appeared to maintain the target at a constant angle with respect to the direction of the car's current heading, with increasing variability as they approached the target. Interception accuracy with visible target was significantly higher than that with invisible target ($p < 0.01$). After the target disappeared in a trial, participants usually directed their gaze in the direction of the car's heading, which was accompanied by a lack of effective steering adjustment. The results are indicative of the active role of eye movement in locomotor interception and the adaptiveness of locomotor control.

53.3018 Automatic shape processing and visuomotor corrections during grasping

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In a previous study, we demonstrated that grasp points for smooth irregular shapes can be determined during an ongoing movement (Chen & Saunders, 2015). When the shape of a target object was unexpectedly changed during a virtual grasping movement, subjects made smooth corrective adjustments toward appropriate contact points for the new target object, detectable within about 300 ms. In this study, we presented task-irrelevant shape perturbations during movements to test whether corrective responses are automatic, or can be suppressed volitionally. Subjects reached to touch projected 2D objects with smooth irregular shapes at locations they would use to grasp the objects. In Experiment 1, half of the trials had transient perturbations in which the target object was replaced by a different object for 200 ms and then reappeared. Subjects were told that the original object would always reappear and were asked to ignore the perturbations. Despite the instructions, we observed automatic corrective adjustments to the grip axis, with similar latency as in the previous study. Experiment 2 tested similar conditions, but subjects were instructed to stop their movement and withdraw their hand as soon as they detected a perturbation. Perturbations were only present on 10% of trials to discourage compensatory strategies. We again observed automatic adjustments of the grip in response to shape perturbations, with similar latency. The grip adjustments continued even after the forward motion of the hand had been stopped, indicating that automatic adjustments co-occurred with volitional control. These results indicate that grip adjustments in response to updated shape information occur automatically and beyond the control of volition.

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53.3019 **Proprioceptive contributions to online limb-target regulation processes?** Valentin Crainic[1](valentin.crainic@mail.utoronto.ca), Stephen Bested[1], John de Grosbois[1], Rachel Goodman[1], Luc Tremblay[1]; [1]Faculty of Kinesiology and Physical Education, University of Toronto

Background: Online control processes are used during goal-directed movements to ensure that the limb reaches the target. Some of these online corrections require contrasting the position of the limb vs. the target (i.e., limb-target regulation) and have been presumed to require visual and proprioceptive inputs (Elliott et al., 2010). In the current study, we sought to investigate the importance of proprioceptive information for the implementation of online limb-target regulation processes. Methods: Thirteen participants were asked to perform rapid goal-directed reaches with tendon vibrators on the distal biceps and triceps brachii tendons and while wearing liquid-crystal goggles. Trials began with participants fixating to the start position. Then, the target appeared (30 cm amplitude) which prompted participants to initiate a saccade and a reaching movement. After that, the goggles were occluded. Then, on one third of the trials, the location of the target was shifted 3 cm closer to the participant. Before achieving peak limb velocity, participants were provided with a brief visual window (20ms), to see the original or jumped target (and their hand). On separate blocks of trials, tendon vibration was applied between trials to both the biceps and triceps, to decrease the sensitivity of the muscle spindles (Ribot-Ciscar et al., 1998). Results: Tendon vibration led to shorter movement times, which were explained by shorter limb deceleration phase durations. In contrast, seeing the jumped target location for 20 ms always led to a shift in the endpoint distributions (4.7 mm), as compared to when the original target was seen during the brief window regardless of the presence of vibration. Conclusion: While the proprioceptive perturbation did influence the motor performance, the limb-target regulation processes associated with the target jump did not significantly differ across tendon vibration conditions. Altogether, online limb-target regulation processes are predominantly visuomotor in nature.

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53.3020 **Limb and target vision differentially contribute to the multiple processes of online control** John de Grosbois[1,2,3], Luc Tremblay[1,2,3]; [1]University of Toronto, [2]Centre for Motor Control, [3]Perceptual Motor Behaviour Lab

Introduction. Elliott et al.'s multiple processes model of discrete reaching movements (2011) proposed two different forms of visually mediated online control (i.e., impulse regulation and limb-target regulation). Vision of the target is likely of greater importance for the limb-target regulation process than for the impulse regulation process. Recently, Tremblay et al., (2013) argued that impulse regulation may be better associated with measures of movement consistency (e.g., variable error: VE), whereas limb-target regulation should influence correlational measures of online control to a greater extent (e.g., Fisher2; de Grosbois & Tremblay, 2015). If this proposal is correct, then limb visibility should primarily influence VE while both the limb and target should be visible to influence Fisher2 values. Methods. Participants (n = 21) completed medial-to-lateral reaching movements in complete darkness. Limb and target visibility were mediated dim, green, light emitting diodes (LEDs). Each trial began with a preview of the finger location and a target location (i.e., either 10 or 30 cm away). Four vision conditions were employed by extinguishing LEDs, or not, upon movement initiation (i.e., limb-visible; target-visible; both visible; or neither visible). Results. Analyses of VE and Fisher2 in the primary movement axis were conducted as 2 Target x 2 Limb Visibility x 2 Target Visibility repeated measures ANOVAs. For VE, adding vision of the limb or the target both yielded better endpoint precision. For the Fisher2, adding vision of the target-only did not yield different correlation values. That is, the addition of target visibility decreased the Fisher2 values only when the limb was also visible. Conclusions. In the primary movement axis, correlational measures of online control (i.e., Fisher2) are specifically sensitive to limb-target regulation processes whereas endpoint precision measures (i.e., VE) are sensitive to all forms of online control. These results also further support the multiple processes model of online movement control.

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53.3021 **Judging endpoint accuracy with brief monocular visual cues** Tristan Loria[1](luc.tremblay@utoronto.ca), Damian Manzone[2], Valentin Crainic[1], Luc Tremblay[1]; [1]Faculty of Kinesiology and Physical Education, University of Toronto, [2]Faculty of Kinesiology, Univeristy of British Columbia

In a previous study of rapid goal-directed reaches with brief visual samples, we observed that visual information gathered by the dominant eye (cf. non-dominant eye) is sufficient to engage in online trajectory amendments. However, it is not clear if this dominant eye advantage is due to perceptual or sensorimotor processes. To elucidate this question, we asked participants to make perceptual estimations about their endpoint accuracy based on a very brief visual sample provided during the movement. If the dominant eye advantage for online control is perceptual in nature, then judgments should be better with dominant than non-dominant monocular information. In contrast, comparable judgments across vision conditions would point to a sensorimotor explanation. Participants (n = 12) performed a 30 cm reaching movement to a target while wearing liquid crystal goggles. During the reaching movement, the goggles provided monocular dominant, monocular non-dominant, or binocular information for 20 ms. After each movement, participants reported whether their endpoint had undershot or overshot the target. A 2 Judgment (undershoot or overshoot) x 3 Vision condition (monocular dominant, monocular non-dominant, and binocular) repeated measures ANOVA contrasted the average movement endpoint and variability results. A main effect of judgment was observed for average endpoint location, which simply indicated that participants were able to use the 20 ms of vision to judge if their limb was about to yield shorter or longer movement amplitudes. Also, trials judged as overshoots yielded larger variable error values than those judged as undershoots. However, these effects were true across all vision conditions, which did not differ from each other. Thus, judgments of target undershoot vs. overshoot can be obtained from brief monocular dominant and non-dominant cues as well as from brief binocular cues. Consequently, the monocular dominant eye advantage for online trajectory amendments requires further investigations.

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Perception and Action: Methods, theories and models

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

53.3022 **About measuring reaction times** Eli Brenner[1](e.brenner@fbw.vu.nl), Jeroen Smeets[1]; [1]Department of Human Movement Sciences, Vrije Universiteit

One way to estimate how long it takes to process visual information is by measuring reaction times. How much longer it takes to respond to a certain aspect of a visual stimulus than to respond to a similar stimulus when the aspect in question does not need to be processed can give you an indication of how long it takes to do the processing. Reaction times are easily measured by asking people to press or release a button. However, responses can differ in vigor as well as in latency. We suspected that the latencies of less vigorous responses might be overestimated when relying on buttons to determine the reaction time. To examine whether this is true, participants were asked to lift their finger off a button as soon as they heard a tone. We compared two conditions. In one condition there was a straw balancing across two blocks just above the button. Participants were told not to knock the straw off the blocks. In the other condition there was no straw. Otherwise the conditions were identical. When we used the moment at which the finger released the button as the reaction time, we found that the reaction time was significantly longer in the presence of the straw. Since our button was actually a force sensor, we could also determine the moment at which the force started to change. When reaction time was measured in this manner, the straw did not influence the judged latency. Thus, the way in which the reaction time is measured can influence the conclusion that we draw from the data. As properties of a stimulus can influence the magnitude of the response as well as its latency, it is important to be aware that the magnitude of the response might influence the estimated latency.

53.3023 **Visual but not proprioceptive signals contribute to detection of sensory-motor perturbation** Elon Gaffin-Cahn[1](eg.gc@nyu.edu), Todd Hudson[2,3], Michael Landy[1,4]; [1]Department of Psychology, New York University, [2]Department of Rehabilitation Medicine, NYU Langone Medical Center, [3]Department of Neurology, NYU Langone Medical Center, [4]Center for Neural Science, New York University

To measure the extent to which the motor system compensates for motor error, studies of motor learning and adaptation typically perturb visual or proprioceptive feedback and measure the compensatory response. These perturbations are often large compared to trial-to-trial error to increase the signal-to-noise ratio of compensatory responses. However, large, detectable

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perturbations can be unnatural and allow subjects to use conscious mechanisms for compensation. Conscious, explicit motor compensation processes may have different parameters and recruit different neural circuitry compared to low-level, automatic mechanisms. To isolate low-level mechanisms, alternative experimental designs provide increased power per trial while using small perturbations so that subjects are unaware of the perturbation. However, to maximize the signal-to-noise ratio of compensation measurements, perturbations should still be as large as possible while remaining unnoticed. We measured the upper limit of undetectable perturbations. We also investigated how subjects combined perturbed visual feedback with the proprioceptive signal to estimate self-generated motor error. Participants made fast center-out reaches on a tabletop while viewing a frontoparallel monitor. On half of these reaches, feedback was perturbed in either gain or direction. No visual feedback of the finger position was displayed on the monitor except for the final, possibly perturbed, reach endpoint. Subjects indicated whether they believed the trajectory had been perturbed, at which point the true reach endpoint was displayed. Participants reliably detected perturbations larger than 1.5 times the trial-to-trial endpoint SD. Detection was primarily a function of displayed visual error feedback, indicating a nearly complete disregard of proprioceptive information. Subjects may be unable to combine visual and proprioceptive feedback to detect perturbation when there is spatial separation between the hand and feedback and/or may downweight proprioception in this task because it is too unreliable.

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53.3024 **Humans exhibit discrete confidence levels in perceptual decision-making** Matteo Lisi[1](matteo.lisi@parisdescartes.fr), Gianluigi Mongillo[2], Andrei Gorea[1]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes & CNRS, [2]Centre de Neurophysique, Physiologie et Pathologie, Université Paris Descartes & CNRS

Animals (including humans) are able to assess the quality of incoming sensory information and act accordingly while taking decisions. The computations underlying such ability are unclear. If neuronal activity encodes probability distributions over sensory variables, then uncertainty – hence confidence – about their value is explicitly represented and, at least in principle, readily accessible. On the other hand, if neuronal activity encodes point-estimates, then confidence must be obtained by comparing the level of the evoked response to fixed (possibly learned) criteria. To address this issue we developed a novel task allowing the behavioral read-out of confidence on a trial-by-trial basis. Each trial consisted of two consecutive decisions on whether a given signal was above or below some reference value, call it zero. The first decision was to be made on a signal uniformly drawn from an interval centered at zero. Correct/incorrect responses resulted into signals uniformly drawn from the positive/negative sub-intervals to be judged when making the second decision, and subjects were told so. The task reliably elicited confidence assessments as demonstrated by the finding that second decisions were more frequently correct than first decisions. We compared the ability of Bayesian and non-Bayesian observers to predict the empirically observed pattern of both first and second decisions. The non-Bayesian observer was designed to have discrete confidence levels instantiated by one or more second-decision criteria representing different levels of the evoked response. Different confidence levels resulted into different second-decision criteria. The non-Bayesian observer with two-three confidence levels systematically (over 9 subjects) outperformed the Bayesian observer in predicting the actual behavior. Hence, contrary to previous claims, confidence appears to be a discrete rather than continuous quantity. Simple heuristics are sufficient to account for confidence assessment by humans making perceptual decisions.

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53.3025 **Biophysically plausible neural model for the interaction between action observation and action execution** Mohammad Hovaidi Ardestani[1,2](mohammad.hovaidi-ardestani@uni-tuebingen.de), Martin Giese[1]; [1]Section for Computational Sensomotorics, Department of Cognitive Neurology, Hertie Institute for Clinical Brain Research, and Centre for Integrative Neuroscience, University Clinic Tübingen, D-72076 Tübingen, Germany, [2]IMPRS for Cognitive and Systems Neuroscience, University of Tübingen, Germany

INTRODUCTION: It has been suggested that neural representations for action perception and action execution are closely linked in the human brain. Previous studies show that the execution of motor behavior influences concurrent visual action observation, and specifically the perception of biological motion. The detailed neural mechanisms that support this interaction are unknown. METHODS: We extended a physiologically-inspired model for visual action recognition (Fleischer et. al. J. Nsc. 2013) by a neural representation of motor programs, which is coupled reciprocally with visual recognition layer that is modeled by a dynamic neural network. Visual and executed actions are represented by a localized activation maxima that propagates in the visual and in the motor representation, which are modeled by dynamic neural fields that are implemented with biophysically realistic spiking neurons. An appropriately designed coupling between both representations results in interactions between action observation and action execution that mimic experimental results on the interactions between motor execution and recognition (Christensen et al., J. Nsc. 2011; Kilner et al., 2003). RESULTS: Consistent with the experimental data, we find a facilitation of the detection of visual action patterns by concurrent motor execution if the executed motor pattern is spatio-temporally compatible with the observed pattern, and interference if it is incoherent, e.g. in presence of time delays between observed and executed actions. CONCLUSION: Simple dynamic neural networks with biophysically realistic neurons can reproduce basic signatures of perception-action coupling in behavioral experiments.

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53.3026 **Both Perception and Action Are Biased by Local Motion When Reporting the Location of a Moving Target** Daryn Blanc-Goldhammer[1](darynbg@gmail.com), Maria-Alejandra De Araujo Sanchez[1], Paul Dassonville[1]; [1]Department of Psychology & Institute of Neuroscience, University of Oregon

When seen in the periphery, the perceived trajectory of a moving target is altered by the presence of local motion within the target (Tse & De Valois, 2006). In spite of this dramatic perceptual effect, there is evidence that targeting movements of the eye and hand are either less affected by the illusion (Lisi & Cavanagh, VSS 2014, 2015), or altogether unaffected (Lisi & Cavanagh, Current Biology 2015). However, it remains unclear whether this apparent dissociation reflects fundamental differences in the processing of visual motion for perception and action, or rather differences in the task requirements, since the perceptual tasks required the observer to report on the target's trajectory (or the allocentric relationship between the motion path's start and end), while the action tasks involved movements guided to the target's egocentric location. In two experiments, we assessed the accuracy of the perceptual and action systems in indicating the location of the start and end of a target's motion path. In Experiment 1, participants were asked to indicate these locations with either a saccadic eye movement, or by using a mouse to move a cursor. In both conditions, responses were significantly affected by the illusion, with reports of the end location biased in the same direction as the local motion, while reports of the starting location were biased in the opposite direction. In Experiment 2, subjects were asked to perceptually compare the location of the start or end of the motion path with a flash that preceded or followed the motion, respectively. As in Experiment 1, the perceived end of the motion path was biased in the same direction as the local motion, while the perceived start was biased in the opposite direction. These findings indicate that both perception and actions are fooled by the illusion when indicating the target's location.

53.3027 **The visual neighborhood in human crowds: Metric vs. Topological Hypotheses** Trenton Wirth[1](trenton_wirth@brown.edu), William Warren[1]; [1]Brown University

Collective motion in human crowds is thought to emerge from local interactions between individual pedestrians. A key problem in understanding these interactions is the structure of a pedestrian's visual neighborhood, that is, which neighbors influence the pedestrian's behavior. Several hypotheses have been proposed (Strandburg-Peshkin, et al. 2013). The metric hypothesis (Reynolds, 1987; Helbing & Molnar, 1995) supposes that a pedestrian is coupled to all neighbors within a fixed distance, or metric radius. The topological hypothesis (Ballerini, et al., 2008) supposes that a pedestrian is coupled to a fixed number of nearest neighbors, regardless of their distance. We dissociate these hypotheses by manipulating the density of neighbors in a virtual crowd. The metric hypothesis predicts that a pedestrian's response should depend on density, whereas the topological hypothesis predicts it should not. Participants wore a head-mounted display and walked in a crowd of virtual humans, while head trajectory was recorded. During the trial, a subset of the nearest neighbors (S=0, 2, 4, 6) turned 10° left or right, and participants were instructed to "walk with" the crowd. In Experiment 1 (N=11), the 6 nearest neighbors appeared at constant distances (.25m apart in depth), while the density of the remaining 18 neighbors was varied (.25m, .50m apart in depth). Mean final heading direction increased linearly

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with subset S (p< .001), but more steeply in the low density than the high density condition (p< .035 at S=6), as predicted by the metric hypothesis. In Experiment 2, we test 12 neighbors at more extreme densities that predict a greater difference in final heading (4, 8 or 12 within estimated radius of 4 m). The results are contrary to the topological hypothesis, but are consistent with a metric visual neighborhood. Related findings suggest a flexible metric radius that may depend on the distance of the nearest neighbor.

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53.3028 Impact of tool function knowledge on visually-informed mechanical problem solving

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Learning about tool function can occur through active experiences, observation of others, and theoretical descriptions (e.g. reading). Previous research suggests that prior knowledge of function interferes with discovering alternative tool functions. Here, we asked whether acquiring knowledge about function through different modalities generates interference in problem-solving contexts where only visual information is available. After assessments (Intuitive Physics, Grooved Pegboard), 118 participants were randomly assigned to one training (Manual, Video, Reading) or control (Alternative-Use, No-training) condition and asked to solve 6 mechanical problem-solving tasks. Importantly, participants in the training conditions had to identify alternative functions to solve the problems, but participants in the control conditions did not. During Manual training, participants learned to manually use novel tools; during Video training, participants watched an experimenter using them; during Reading training, participants saw a picture and read how to use them; during Alternative-Use training, participants watched an experimenter and learned the alternative function needed to solve each mechanical task; and for the No-training condition, participants were not trained. Participants had a maximum of 2 attempts to solve each task. Each attempt involved a planning session when participants visually inspected a task apparatus with 3 tools, immediately followed by an execution session when they enacted their chosen solution with their chosen tool. A multiple regression with total time in both attempts as DV provided a significant effect for training condition, intuitive physics, and task (adj.R2=.26). Interestingly, participants in control conditions tended to be faster than those in training conditions. However, when predicting only planning among those who solved the task in the first attempt, participants in the Reading condition tended to be slower than the remaining (adj.R2=.36). Results suggest that the modality of knowledge acquisition when learning about tool function can affect planning and execution time in problem-solving contexts reliant upon only visual information.

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53.3029 Executive Control in Manual Affordances

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Mere perception of a familiar object automatically leads to the activation of corresponding motor programs representing typical actions with this object also known as affordances. Despite substantial research, the issue of a control over irrelevantly potentiated affordances remains unclear. However, two theoretical accounts are can be entertained: (1) automatic and unintended self-inhibitory process or (2) intended and active process due to executive control. We tested these two accounts in two experiments using a dual-task paradigm: The lateral affordance task was accompanied by a parallel interference task (backward-counting in Experiment 1 and auditory Stroop in Experiment 2). In both Experiments the affordance task was the same: Participants were presented with photographs of graspable objects and asked to classify these as upright/inverted by making left-/right-hand responses. Objects' handles were also oriented leftward or rightward resulting in match/mismatch response condition. A central inhibition account predicts that the decrease in cognitive resource due to the dual-task scenario should lead to the disinhibition of potentiated actions and positively modulate the corresponding stimulus-response compatibility (SRC) effect. A self-inhibition account predicts that the depletion of cognitive resources due to the dual-task scenario should result in the self-inhibition of irrelevantly potentiated affordances leading to the attribution of an inverted SRC effect. We registered (1) an inverse SRC effect in Experiment 1 and (2) no SRC effect – in Experiment 2. Our results, therefore, provide partial support to the self-inhibition account. We propose that in supraliminal conditions a threshold for self-inhibition is raised because more efficient mechanism of monitoring is available. At the same time, the threshold drops when monitoring is unavailable, and the inverse SRC is observed. Finally, our data imply that different executive processes may play distinct roles in controlling manual affordances.

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53.3030 Perceiving one's own invisible body through subjective completion of body parts with vision–action contingency

Ryota Kondo[1](kondo@real.cs.tut.ac.jp), Masahiko Inami[2], Michiteru Kitazaki[3]; [1]Graduate School of Engineering, Toyohashi University of Technology, [2]Graduate School of Information Science and Technology, the University of Tokyo, [3]Department of Computer Science and Engineering, Toyohashi University of Technology

Body ownership can be modulated through illusory visual–tactile integrations (Botvinick and Cohen, 1998) or observing mirror reflections of motor actions (Gonzalez-Franco et al., 2010). Illusory ownership of an invisible body is induced by the illusory visual–tactile integration (Guterstam et al., 2015). However, this method does not make us perceive our body shape or action. We aimed to develop a method to perceive one's own invisible body in shape and action through real-time visual motions of the hands and feet contingent with observers' actions and to evaluate its effect on perception. Twenty participants observed left and right white gloves and socks in front of them at a distance of 2 meters in a virtual room through a head-mounted display (Oculus Rift DK2, 90×110 deg). They wore white gloves and socks before the experiments and answered 8 questions on 7-point scales after 5 min of observation with voluntary actions. In half the trials, their actions were captured by a motion sensor (Kinect2), and the hands and feet in a virtual-reality environment moved contingently with their own actions. In the remaining, the hands and feet were virtually attached to another person and moved independently of the participants. We found that participants rated perception of their own invisible body between the hands and feet significantly higher in the vision–action contingent than in the independent condition. Thus, this phenomenon required vision–action contingency and elicited perception of a complex shape and action of an invisible body. We presented a knife to threaten the participants after their invisible body experiences. Participants avoided the knife more often in the contingent condition, but the difference was not statistically significant. This suggests that we can observe our own invisible bodies by completing body parts only from visible hands and feet if their motions are contingent with our actions.

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53.3031 Body size estimations: the role of visual information from a first-person and mirror perspective

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Our perception of our body, and its size, is important for many aspects of everyday life. Using a variety of measures, previous research demonstrated that people typically overestimate the size of their bodies (Longo & Haggard, 2010). Given that self-body size perception is informed from many different experiences, it is surprising that people do not perceive their bodies veridically. Here, we asked, whether different visual experiences of our bodies influence how large we estimate our body's size. Specifically, participants estimated the width of four different body parts (feet, hips, shoulders, and head) as well as a noncorporeal object with No Visual Access, Self-Observation (1st person visual access), or looking through a Mirror (2nd person visual access) using a visual matching task. If estimates when given visual access (through mirror or 1st person perspective) differ from estimates made with no visual access, it would suggest that this method of viewing one's body has less influence on how we represent the size of our bodies. Consistent with previous research, results demonstrated that in all conditions, each body part was overestimated. Interestingly, in the No Visual Access and Mirror conditions, the degree of overestimation was larger for upper body parts compared to lower body parts and there were no significant differences between the No Visual Access and Mirror conditions. There was,

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however, a significant difference between the Self-Observation condition and the other two conditions when estimating ones shoulder width. In the Self-Observation condition, participants were more accurate with estimating shoulder width. The similarity of results in the No Visual Access and Mirror conditions suggests that our representation of our body size may be partly based on experiences viewing one's body in reflective surfaces.

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Visual Search: Models and mechanisms

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

53.3032 Peripheral vision contributions to contextual cueing

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Contextual cueing leads to faster search times in repeated displays. The global layout of a search display facilitates search in repeated displays (Brady & Chun, 2007). However, peripheral vision can only convey a limited amount of information about the environment. We used a model of visual summary statistics (Portilla & Simoncelli, 2000; Balas 2006) to investigate the contribution of peripheral vision to contextual cueing. Summary statistics were calculated over areas that grew in size with eccentricity (Freeman & Simoncelli, 2011), simulating the receptive field sizes in visual area V2. The contribution of peripheral vision was tested with brief previews (150 ms) of the viewpoint-dependent synthesized full-field metameric model displays or original displays prior to search for a target T among L-shapes that was restricted to a gaze-contingent tunnel abolishing peripheral vision and, thereby, preventing context learning (Geringswald & Pollmann, 2015). Preview benefits were measured in a subsequent test phase with full-field search in the same repeated and novel original displays. In Experiment 1, we investigated whether a preview of 20 different model displays representing the summary statistics of the same original display leads to the same size of contextual cueing as previewing the same original display 20 times. Both original and model previews led to significant contextual cueing of comparable size. In Experiment 2, we examined the contribution of form and location information represented in the summary statistics by comparing the full model displays from Experiment 1 to models of displays, in which L and T shapes were replaced by identical crosses, eliminating form information. Both full models and spatial models led to significant contextual cueing, with no significant difference between conditions. Thus, visual summary statistics modeling receptive field sizes in V2 are sufficient to generate contextual cueing in visual search, even if they contain only the spatial layout of a display.

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53.3033 Visual Search for Multiple Targets in Probabilistic Environments

Yelda Semizer[1](yelda.semizer@rutgers.edu), Kimele Persaud[1], Xiaoli He[1], Nicholas Kleene[1], Omer Tanrikulu[1]; [1]Rutgers University

Active visual search requires finding targets in environments where target presence in local regions is probabilistic and search is costly in time or energy. Efficient strategies take both probabilities and costs into account (Hutchinson et al. 2008; Wolfe, 2013). To understand search strategies, we studied active search for hidden targets (revealed by mouse clicks) when location probabilities and costs varied. Three virtual "rooms" were displayed, each with 4 possible locations (colored squares) that might contain a hidden target. The probability of a target being present in any location was chosen independently and indicated by the color of the square. Probabilities were chosen such that the overall probability of finding targets in any given room was different. Points were rewarded for targets found, and deducted for each location searched. Participants navigated between rooms using a mouse, attempting to accumulate as many points as possible. Across blocks we manipulated search costs: points deducted/search, the time to travel to a room, and the total time/trial. Participants were tested over 8 days, 1120 trials. Subjects' search strategies favored rooms with higher overall probabilities, particularly with the stricter time limits. Time penalties (points deducted/location searched; travel time between rooms) were less influential. Strategies were biased by the success of recent outcomes, despite the fact that the target probabilities were independent. In most cases, observers under-performed relative to models that took into account both probability and time costs. These results suggest that human observers were biased to overweigh cues about probabilities and recent search experience, and underweight the role of time costs.

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53.3034 Examining Confirmatory Strategies in Visual Search: People are more flexible than you think

Stephen Walenchok[1](swalench@asu.edu), Stephen Goldinger[1], Michael Hout[2]; [1]Arizona State University, [2]New Mexico State University

Visual search, by definition, entails confirming whether an object of interest is present or not. However, the role of disconfirmation in search is often overlooked. For example, imagine that you are at a party, and your friend asks you to retrieve an apple that he spotted earlier on the fruit platter. Apples are typically red, so you direct your attention to red fruit. However, the only red fruit that you find are strawberries. You therefore conclude that the apple must be green, by process-of-elimination. Recent research from Rajsic, Wilson, & Pratt (2015) suggests that people are biased to use a confirmatory strategy when searching, however, even when that strategy is not optimal. Their participants searched through displays of letters presented in two possible colors, indicating whether or not a target letter matched an initially-provided template color. Critically, the optimal strategy was always to restrict search to the smaller subset of colored letters, using process-of-elimination if necessary (e.g., if 25% are red and 75% are green, only look at the red letters). Nonetheless, people perseverated in searching through template-matching colors (i.e., even when the majority of letters matched the template color, entailing more laborious search). Might people adopt a more flexible strategy when the target letter only rarely occurs in the template-matching color? We examined this question by manipulating the prevalence of template-matching and template-mismatching targets. We also had participants terminate search and verify the target with separate responses to minimize motor errors. When targets frequently matched the template color, people largely used a confirmatory strategy. However, people adopted a more flexible strategy when template-matching targets were rare, and, surprisingly, when target colors were equally probable, in stark contrast to Rajsic, et al. (2015). These results suggest that the search strategies that people adopt are more malleable than previous findings suggest.

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53.3035 Adding a Dimension to Visual Search

Dawn Sarno[1](dawn.sarno@Knights.ucf.edu), Joanna Lewis[1], Mark Neider[1]; [1]Psychology, College of Sciences, University of Central Florida

Previous research on the interaction between visual search and depth information has suggested that adding depth information can facilitate search performance (e.g., faster RTs for 3-D vs 2-D displays). In the present study we aimed to replicate these previous findings while controlling for potential confounds (e.g., size). Search arrays were constructed from oriented "T" targets among oriented "L" distractors at two set sizes (18 & 24). To create a percept of depth, 3-D items were rendered with a bevel at three depths and 2-D stimuli were created at three sizes (to match changes in size related to depth in the 3-D condition) without a bevel. Participants were instructed to search for and respond to the presence of a "T" target on each trial – no specific target preview was provided. In half of the trials the search arrays were presented in 2-D and in the other half they were presented in 3-D. The target position was equally distributed across the three depth planes (3-D trials) and three item sizes (2-D trials) over the course of the experiment. Interestingly, the results were inconsistent with previous findings. Overall accuracy did not vary significantly across any manipulations. RTs in the 2-D condition were faster than in the 3-D condition across set size in both target present (~342 ms and ~549 ms, respectively) and target absent trials (~689 ms and ~884 ms). Additionally, search slopes in the 3-D condition (~85 ms) were steeper than in the 2-D condition (~52 ms). Overall, our results contradict previous findings and suggest that adding depth information does not always elicit performance advantages over 2-D displays during visual search. Further studies to systematically explore how various parameters of depth interact with search behavior and attentional deployment are required.

53.3036 The role of contextual cuing in general improvement

Anna Vaskevich[1](anna.vask@gmail.com), Roy Luria[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, [2]The Sagol School of Neuroscience, Tel-Aviv University

Previous studies have demonstrated that in a visual search task, observers are faster to locate targets when these are presented in repeated rather than random contexts, an effect termed contextual-cuing. Using a random mapping condition and a consistent mapping condition, in which targets and distractor-sets were paired throughout the experiment, we replicated

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this classic effect (Experiment 1), and conducted two experiments aimed at clarifying how contextual cuing interacts with general task improvement (i.e., learning). We used either repeated contexts only (Experiment 2) or random contexts only (Experiment 3), and found that learning curves were similar in both experiments and, surprisingly, much faster than in Experiment 1. Our results suggest that contextual-cuing does not facilitate general learning performance. Instead, an advantage for a repeated context condition seems to be observed only when it is intermixed within a random context condition. To better understand whether our results are specific to contextual cuing, or can be generally applied to other kinds of implicit learning, we conducted two more experiments with a discrimination task. Participants were instructed to answer as fast as possible which image (out of four possibilities) is presented. In Experiment 4, images appeared at random locations, while in experiment 5 images appeared according to a specific 9-elements spatial order. Results were similar to the contextual cuing paradigm experiments. In general, our results question the current view of statistical learning as a mechanism that supports general learning improvements. We argue that the contextual-cuing effect is not a result of facilitation from repeated contexts, but rather reflects overcoming interference caused by mixing regularities and randomness.

53.3037 **Why are the Batteries in the Microwave?: Use of Semantic Information Under Uncertainty in a Search Task** Gwendolyn Rehrig[1,3](gwendolyn.rehrig@rutgers.edu), Michelle Cheng[1,3], Brian McMahan[1,2], Rahul Shome[2]; [1]Department of Psychology, [2]Department of Computer Science, [3]Rutgers Center for Cognitive Science

Observers use prior expectations to inform their searching behavior within an environment to facilitate efficient visual search (Aydemir et al., 2013). Search decisions may reflect this bias even when it is contradicted by recent experience (Võ & Wolfe, 2012; 2013). We asked whether searchers can learn to incorporate evidence that contradicts their prior expectations with practice. To estimate prior expectations, 185 participants rated how likely common household objects were to be found in each of 12 locations (6 in the living room and 6 in the kitchen). Then, a separate group of 10 participants searched through two virtual rooms (kitchen and living room) for one of 3 target objects. Objects were hidden from view in the scene and revealed by a mouseclick. Points were awarded for finding a target before the end of each 30s trial, and more points were awarded for searching quickly. Time was expended in clicking locations and traveling between rooms. Three search environments were created in which targets appeared in likely, unlikely, or uniform locations, where location likelihood was determined from the initial ratings. The three environments were tested in separate blocks of trials. We found that there were two types of searchers: those who adapted to the environment quickly when the episodic information did not match prior expectations, and those who required repeated searches in order to learn new sets of expectations. Results were consistent with a Bayesian decision model in which the prior expectations were either consistent with the ratings, inverted, or uniform. Searchers who took more time to adapt to the environment either did not construct a new prior to account for recent experience, or assumed all target locations were random. The findings indicate different individual preferences to form new expectations to fit recent experiences.

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53.3038 **The size congruity effect in visual search for digits involves both facilitation and interference** Amrita Puri[1](apuri@ilstu.edu), Kenith Sobel[2], Nikolas Sieg[2], Zachery Stillman[1]; [1]Department of Psychology, Illinois State University, [2]Department of Psychology and Counseling, University of Central Arkansas

Consistent with the size congruity effect (SCE) reported in digit comparison tasks (Henik & Tzelgov, 1982) and findings that semantic meaning influences visual search for digits (Sobel et al., 2015), a recent report suggests that searching for numerically large or small digits among distractors that differ from the target in both numerical and physical size is faster when numerical and physical size are congruent compared to when they are incongruent (Sobel & Puri, 2014). We investigated whether the SCE in visual search is due to interference between semantic and perceptual information on incongruent trials, facilitation of search on congruent trials, or both. Participants searched for three-digit target numbers that were either less than 500 (numerically small) or greater than 500 (numerically large) within displays containing four, six, or eight distractors. Targets could also be physically small among medium and large distractors, medium among small and large distractors, or large among small and medium distractors. Thus, on congruent trials, targets were either numerically and physically large or numerically and physically small, and on incongruent trials, targets were either numerically large but physically small or numerically small but physically large. Furthermore, a third set of trials involved congruence-neutral targets, which were numerically small or numerically large but physically medium, presented among physically large and physically small distractors. All conditions were within subjects, with numerically large vs. numerically small targets presented in blocks, and congruent, incongruent, and neutral trials randomly interleaved. Participants reported whether targets were on the left or right of the display. A main effect of congruence on reaction times was due to faster RTs in the congruent conditions and slower RTs in the incongruent conditions compared to the neutral conditions, suggesting both facilitation on congruent trials and interference on incongruent trials.

53.3039 **The Effects of Blur/Clarity Contrast on Visual Selective Attention** Jared Peterson[1](jaredpeterson@k-state.edu), Ryan Ringer[1], Michele Riter[1], Elizabeth Sisco[1], Maria De La Torre[1], Shobha Subedi[1], Lester Loschky[1]; [1]Psychological Sciences, Arts and Sciences, Kansas State University

The detection of visual blur during a dual task has been shown to be unaffected by cognitive load (Loschky et al., 2014). Blur may be a feature that can be detected preattentively, such as color, orientation, etc. (Treisman & Gelade, 1980). Interestingly, eyetracking studies have shown when blur/clarity contrast is present in a scene, eye movements during free viewing tend to go to regions of clarity rather than blur (Enns & MacDonald, 2012; Kahn, Dinet, & Konik, 2011; Loschky & McConkie, 2002; Smith & Tadmor, 2012). However, these issues have not been studied in the context of visual search, the "gold standard" of attentional selection research. Thus, an eyetracking visual search study investigated if blur/clarity contrast is non-predictive of a target, will unique blur capture or repel visual selective attention or be ignored? A legibility control study showed that identification accuracy and reaction times did not significantly differ between blurred or clear single rotated T-like Ls or Ts (Jiang & Chun, 2001); thus legibility would not explain search results. Then, a rotated L versus T visual search task was performed with an imaginary circle of eight degrees radius, and set sizes 4 & 8, using the control study stimuli. Letters were presented either all-blurred, all-clear, or with a blurred or clear singleton letter among distractors. With set size 4, reaction times weakly supported unique blur being ignored (blurred singleton target = all-blurred). With set size 8, reaction times strongly supported unique blur being ignored (blurred singleton target = all-blurred = all-clear) and clarity captured visual selective attention (clear singleton target < all-clear & blurred singleton target). Eyetracking results further supported these conclusions. In set size 8, the first eye movement to a letter most frequently landed on a uniquely clear letter, but not uniquely blurred letters. Overall, the results suggest that unique clarity captures attention while unique blur is ignored.

53.3040 **The role of reinforcement in "optimal" search strategies** Bobby Stuijfzand[1](bg.stuijfzand@bristol.ac.uk), Roland Baddeley[1], William Browne[2]; [1]School of Experimental Psychology, University of Bristol, UK, [2]Graduate School of Education, University of Bristol, UK

Highly trained observers can show near-optimal visual search strategies, similar to those of a Bayesian ideal observer. Based on two participants, Najemnik & Geisler (2005, 2008) demonstrate that optimal search can be identified with a stereotypical pattern of eye movements when searching for a target (short horizontal saccades and occasional jumps into "unknown" vertical space). We explored the optimality of visual search by conducting a study based on the previous search task, involving searching for a small gabor target in a circular background of 1/f noise. Twenty participants completed 160 trials, distributed over four blocks with four different target contrasts. We fitted a 2-state hidden Markov model to test whether the resulting temporal saccade distribution was consistent with the optimal pattern but, contrary to expectation, found idiosyncratic rather than optimal search strategies. We therefore propose a simpler model for visual search where optimality is achieved, not by solving a difficult optimisation problem, but by the application of reinforcement learning. In particular, the application of "reinforce" class of models that has proved successful in artificial models of attention. We tested for evidence of reinforcement by adding a training phase with altered reward statistics to the previously described search task. In the training phase, the target was revealed only after a leftward saccade. Fifteen participants completed 252 trials, distributed over six blocks, the middle four blocks being the training phase. The participants, although naïve to this intervention, demonstrated a clear, significant increase in leftward saccades from pre- to post-training. These findings provide strong evidence for reinforcement learning being involved in optimising visual search strategies and provide a simple explanation of "optimal" behaviour previously found in some observers.

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53.3041 The new best model of visual search can be found in the brain Gregory Zelinsky[1,2](Gregory.Zelinsky@stonybrook.edu), Hossein Adeli[1], Françoise Vitu[3]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University, [3]Laboratoire de Psychologie Cognitive, CNRS, Aix-Marseille Université

Modern image-based models of search prioritize fixation locations using target maps that capture visual evidence for a target goal. But while many such models are biologically plausible, none have looked to the oculomotor system for design inspiration or parameter specification. These models also focus disproportionately on specific target exemplars, ignoring the fact that many important targets are categories (e.g., weapons, tumors). We introduce MASC, a Model of Attention in the Superior Colliculus (SC). MASC differs from other image-based models in that it is grounded in the neurophysiology of the SC, a mid-brain structure implicated in programming saccades—the behaviors to be predicted. It first creates a target map in one of two ways: by comparing a target image to objects in a search display (exemplar search), or by using a SVM-classifier trained on the target category to estimate the probability of search display objects being target category members (categorical search). MASC then projects this target map into the foveally-magnified space of the SC, where cascading operations average priority signals over visual and motor neural populations. Motor populations compete, with the vector average of the winning population determining the next saccade. We evaluated MASC against exemplar and categorical search datasets, where two groups of 15 subjects viewed identical search displays after presentation of exemplar or categorical target cues. MASC predicted saccade-distance traveled to the target and the proportion of immediate target fixations nearly as well as a Subject model created using the leave-one-out method. MASC's success stems from its incorporation of constraints from the saccade programming literature. Whereas most models of search explore different algorithms and parameter spaces to minimize prediction error, MASC takes its parameters directly from the brain. The brain already found the optimal parameters for search, and it is in the brain that we should look for model inspiration.

53.3042 Visual saliency response in the superficial and intermediate superior colliculus and the pupil. Janis Kan[1](kan.janis@queensu.ca), Brian White[1], Chin-An Wang[1], Laurent Itti[2], Douglas Munoz[1]; [1]Centre for Neuroscience Studies, Queen's University, Kingston, Canada, [2]Computer Science Department, University of Southern California, Los Angeles, USA

The superior colliculus (SC) is a phylogenetically old midbrain structure that plays a central role in vision, attention, and orienting. The SC has visual representations in the superficial-layers (SCs), and sensorimotor representations linked to the control of eye movements and attention in the intermediate-layers (SCi). Cognitive and computational neuroscience postulates the existence of a visual saliency map that guides visual orienting towards the most visually conspicuous stimuli, and a priority map that combines bottom-up saliency and top-down relevance to allow internal processes such as goals and expectations to also guide behavior. We hypothesize that the SCs embodies the role of a bottom-up saliency map while the SCi embodies the combined priority map. To test this hypothesis, we compared SCs and SCi activity in response to task-irrelevant salient stimuli. In addition, we will measure any pupillary response, as our lab recently showed a transient pupil response upon the presentation of salient stimuli or SCi microstimulation. Monkeys viewed a wide-field arrangement of stimuli (210 radially-arranged items spanning ~40-50deg) extending beyond the classic receptive field (RF). The stimuli were oriented color-bars (~0.4x1.2deg) that formed a perceptual "pop-out" array the monkeys had to ignore; i.e., reward was contingent upon maintaining gaze on central fixation. We compared visual representations in SCs and SCi when 1 to 4 salient pop-out stimuli appeared equally spaced within the array. We also compared this to an array of homogenous items with no pop-out. Consistent with our previous study, only SCs neurons showed a reliable preference for the visually salient but goal irrelevant pop-out stimulus. Also, this representation was the same in the presence of 1 to 4 pop-out items. Interestingly, we found larger pupillary responses when a pop-out stimulus was presented than when a homogenous array was presented, and this pop-out differentiation began approximately 350ms after array onset.

53.3043 Attending to Multiple Objects Relies on Both Feature- and Dimension-based Control Mechanisms: Evidence from Human Electrophysiology Thomas Töllner[1,2](thomas.toellner@psy.lmu.de), Markus Conci[1], Hermann Müller[1,3], Veronica Mazza[4]; [1]Department of Experimental Psychology, Ludwig-Maximilians-Universität München, [2]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, [3]School of Psychological Sciences, Birkbeck College, University of London, [4]Center for Mind/Brain Sciences, University of Trento

Numerous everyday search tasks require humans to attentionally select and temporally store more than one object present in the visual environment. Recently, several studies sought to isolate the mechanisms underlying such subitizing tasks by means of electrophysiological measures, which led to a more fine-grained picture as to which processing stages are modulated by object numerosity. One critical limitation that all these studies share, however, is that they used stimulus designs in which the targets were exclusively defined by the same feature value. Accordingly, it remains an open issue whether these findings may generalize to search scenarios in which multiple targets are physically not identical. To systematically address this issue, we introduced three target context manipulations, in which multiple targets were randomly defined by (i) the same feature (sF), (ii) different features within the same dimension (dFsD), or (iii) different features across dimensions (dD). Our findings revealed that people's ability to enumerate multiple targets was remarkably influenced by inter-target relationships, with fastest responses for sF trials, slowest responses for dD trials, and responses were of intermediate speed for dFsD trials. Our electrophysiological analyses disclosed that one source of this response slowing was feature-based and originated from the stage of attentional selection (as indexed by PCN waves), whereas another source was dimension-based and associated with working memory processes (as indexed by P3b waves). Overall, our results point to a significant role of inter-target relationships in multiple object processing—a factor that seems to have been largely neglected in most subitizing studies.

53.3044 Real time electroencephalography analysis of brainwaves during perception of visual illusions Sun Zhe[1](n145301c@yokohama-cu.ac.jp), Zhu Li[2], Ruggero Micheletto[1], Andrzej Cichocki[2]; [1]Yokohama City University(Graduate School of Nanobioscience, Micheletto Laboratory), [2]Riken Institute(Brain Science Institute)

Brain sometimes misinterprets visual information and causes the so called optical illusions. In our research, we used a 32-channel electroencephalography (EEG) apparatus to analyze the brain response to several optical illusion stimulus. Four groups of ambiguous patters were prepared: normal patterns that have no illusory stimulus (blank tests) and three other groups of illusory patterns that we name as cognitive (e.g. Necker cube) geometrical (e.g. Müller-Lyer illusion) and physiological (e.g. Hermann grid illusion). After an initial adaptation to the stimulus, for each image, 30 msec of EEG signal was recorded, then subjects took five minutes break before the next test. To analyze the EEG data, firstly we used independent component analysis to reduce the signal noise and calculated the Fourier spectrum of the EEG signal from all of the channels. As found by Rufin VanRullen(The Journal of Neuroscience, 2006), EEG data with Wagon Wheel Illusion stimulus was analyzed, here we used all types of visual illusions and observed response of the brain. We focused on the peaks of the Fourier spectrum in different bandwidth. As we know, EEG signal are subdivided into δ wave (less than 4Hz), θ wave (4-7Hz), α wave (8-15Hz), β wave (16-31Hz), γ wave (greater than 32Hz). The percentage bandwidth of the biggest peak was calculated, we found that when the participant focused on the normal patterns or on cognitive optical illusion graphs, brain generated more γ waves. But with the stimulus of physiological optical illusion and geometrical one, brain generated more β waves. The percentage bandwidth of the three biggest peaks was also calculated, the result show that optical illusion in general stimulates an increase of α waves. Because of this increased α waves, we propose that the optical illusions promote more coherent signal transmission in brains, resulting in more intuition and imagination compared to stable non illusory patterns.

53.3045 Does Hand Position Enhance Target Detection in a Complex, Real-World Search? Ronald Andringa[1], Sadhana Ponnaluri [2], Jason McCarley [3], Walter Boot [1]; [1]Florida State University, [2]Maclay School, [3]Flinders University

Previous research has shown that hand position can influence visual processing in a variety of ways, including enhancing change detection, reducing the effect of distraction, and boosting sensitivity to low-spatial

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frequency information. These studies have largely used abstract laboratory paradigms; in the current study we explored whether enhanced visual analysis in the space near the hands confers an advantage when applied to a real-world visual search task. We asked participants to search for knives in X-ray images of luggage (a TSA luggage screening task). Stimuli were presented on a tablet computer and participants performed the task by pressing response boxes at the edge of the screen, which forced them to grip the display within their hands, or with a button press on a mouse held in their lap. In the first experiment, there was no effect of hand placement on response times ($F(1,67) = 1.50$, $p = .31$) or accuracy ($F(1,67) = .003$, $p = .96$). In another experiment, participants were asked to use their finger to trace along the image of the bag to ensure that all potential target locations were inspected. In addition to any effect of hand proximity, it was anticipated that this strategy would encourage a more systematic search. Preliminary evidence suggests that this strategy resulted in substantially longer inspection times ($F(1,19) = 10.59$, $p < .01$; a slowing of about 1.6 seconds). Interestingly, this additional time spent viewing the image did not improve accuracy ($F(1,19) = 3.18$, $p = .09$; a trend for more false alarms in the finger tracing condition). While basic research suggests that hand proximity can influence visual processing, these experiments suggest that benefits may not scale to more complex situations.

53.3046 **Find one fast, or find them all slow: Do collaborative visual searchers search more quickly or more thoroughly?** Alexis Lopez[1](alopez12@nmsu.edu), Garrett Bennett[1], Arryn Robbins[1], Hayward Godwin[2], Michael Hout[1]; [1]New Mexico State University, USA, [2]University of Southampton, UK

A number of real-world scenarios involve pairs or teams of individuals searching collaboratively for complex targets. In an attempt to examine these types of scenarios, our recent research has demonstrated that, relative to a solo searcher, collaborative searchers exhibit higher response accuracy when engaged in complex visual search tasks. In the present studies, we sought to further mimic the challenges faced by real-world searchers and to better understand collaborative search behavior. In Experiment 1, participants searched for a single target as quickly as possible; in Experiment 2, speed was not emphasized, and participants were told to make sure to find every target that was present. Participants memorized 24 target categories, and were assigned to one of four conditions: a solo search condition; a collaborative group (two searchers working together); a split memory strategy group (where each searcher focused on half the memory set); and a split screen strategy group (where each searcher focused on half of the screen). During search, observers saw arrays of 32 images with between 0-3 targets present on each trial. Participants clicked on target items or a "stop sign" to indicate that their search was concluded (in Experiment 1, trials ended after a single click). In Experiment 1, we found that collaborative search teams made fewer false-alarms and more hits, but RTs were unaffected (and there was no effect of collaborative strategies). In Experiment 2, we found that collaborative searchers made more hits, but were not demonstrably better with respect to false-alarms or RT (and again no effects of search strategy). Our findings suggest that working in a team elicits selective benefits to behavior; team searchers tend to be more accurate but not faster searchers, and commit false-alarms less frequently when under time pressure. Our ongoing research is exploring further the effectiveness of collaborative search strategies.

53.3047 **Solid field of visibility** Sergei Gepshtein[1](sergei@salk.edu); [1]Salk Institute for Biological Studies

Previous attempts to characterize the structure of visual space concentrated on perceived relationships between "objects, backgrounds, and the self" (Indow, 1991), including metric and topological measures of such relationships. I consider a different approach which is simpler and more basic in that it concerns visibility of object and patterns. Indeed, one's experience of the relationship between visual objects and patterns is predicated on the ability to see them. I start by developing a model of the structure of solid space by tracing visibility of patterns as a function of viewing distance. For example, a luminance grating projected on an opaque screen will create a retinal image of increasing spatial frequency as the viewing distance increases. The contrast sensitivity function predicts the distances at which the grating will be visible or not. The boundaries of visibility depend on whether the grating is moving. This approach allows one to predict visibility for every location in the space that contains any three-dimensional arrangement of static and dynamic patterns. Since the predicted visibility has a value for every location and it varies smoothly across locations, I describe the predictions in terms of a "solid field of visibility." The field is made up of solid regions which contain different visual information and which may overlap or nest in one another. The predictions were tested using static and dynamic patterns projected on large screens propelled through space by large-scale robotics at the IDEAS Robotics Laboratory (UCLA Department of Architecture and Urban Design) in collaboration with the architect Greg Lynn (UCLA) and the designer Alex McDowell (USC). The results confirmed predictions of the model in several respects, including spatial locations of the boundaries between solid regions of visibility and the notion that the boundaries are displaced by adding dynamic content to the patterns.

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Attention: Capture, salience, reward

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

53.4001 **Timmy, Lassie, Clyde, Daffy, Hedwig, and Polly: Joint attention effects between human and nonhuman animals** Anna McPhee[1](michelle.mcphee@mail.utoronto.ca), Joseph Manzone[2], Timothy Welsh[1]; [1]Faculty of Kinesiology and Physical Education, University of Toronto, [2]School of Kinesiology, The University of Western Ontario

One non-verbal communication cue that facilitates social interaction is the direction of gaze because it provides a signal regarding another individual's location of interest and attention. Knowing what another individual is attending to allows the observer to reorient their attention to that stimulus so that both individuals are attending to the same stimulus – a phenomenon known as joint attention. Although joint attention has been extensively studied in human-human context, research on human-nonhuman animal interactions is scarce. The present experiments were conducted to examine joint attention between humans and nonhuman animals by investigating whether or not the visual gaze of nonhuman animals can shift a human's attention. Participants completed a simple localization task via a button press response after detecting a target that appeared in a left or right placeholder. Prior to target onset, participants were presented with the head of an animal or human that suddenly changed orientation from a direct (towards the participant) to an averted gaze (towards left or rightward placeholders). Targets were presented randomly in either placeholder location 100, 300, 600, or 1000 ms after the head rotated. The heads were of mammals (human, orangutan, dog) in Experiment 1 or of birds (owl, duck, parrot) in Experiment 2. The analysis of response times (RTs) revealed joint attention effects - RTs were shorter for cued (gazed at) than uncued (not gazed at) locations. Interestingly, although the cuing effects peaked at 300 ms for all animals, cuing effects were still significant at 600 and 1000 ms for the mammals but were not significant for the birds at these times. Thus, the data suggest that humans can engage in joint attention with nonhuman animals, but that these effects might not be as strong or resilient for birds as for mammals.

Acknowledgement: NSERC

53.4002 **Active suppression of salient-but-irrelevant inputs takes time and does not underlie resistance to interference** Dirk Kerzel[1](dirk.kerzel@unige.ch), Caroline Barras[1]; [1]Faculté de Psychologie et des Sciences de l'Education, Université de Genève

We investigated the electrophysiological correlates of resistance to interference from salient-but-irrelevant color singletons. In conditions promoting interference, the target shape was presented among uniform nontargets. Because it was possible to search for any salient singleton instead of a specific shape (singleton detection mode), participants may have selected the color distractor on some trials, which increased reaction times. In conditions avoiding interference, the target shape was embedded in various nontarget shapes (feature search mode), requiring observers to search for a specific shape. We measured event-related potentials (ERPs) to lateralized color singletons in singleton detection and feature search modes. In singleton detection mode, we observed a contralateral positivity (PD) after about 290 ms, suggesting that the salient distractor was suppressed. Because RTs in singleton detection mode increased when a distractor was present, we conclude that active suppression of distractors is a time-consuming process. In feature search mode, neither a PD nor an N2pc occurred, suggesting that the absence of interference is not accomplished by active suppression of salient-but-irrelevant stimuli, but by ignoring them. Further, we observed an early positivity (Ppc) to the color distractor between 125 and 175 ms that is consistent with an "attend-to-me" signal. Finally, the latency of the ERPs were consistent with the summation of the distractor-related PD and the target-related Nt.

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53.4003 Interference from salient-but-irrelevent stimuli is stronger with perceptual ambiguity: Evidence for biased competition

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We investigated how interference from salient distractors is affect by target-nontarget similarity. We presented eight shapes and participants searched for a square target among diamond nontargets in the high similarity condition and for a square target among circle nontargets in the low similarity condition. Participants had to indicate the orientation of the bar inside the square by pressing one of two keys. A color distractor was present on 50% of the trials. Results showed that interference from the color distractor was larger in the high than in the low similarity condition. Additionally, we measured event-related potentials. The strong interference in the high similarity condition was accompanied by a contralateral negativity, the N2pc component, in response to the distractor. In contrast, weak interference in the low similarity condition was accompanied by a contralateral positivity, the PD component, in response to the distractor. Previously, the N2pc component was considered a measure of attentional capture whereas the distractor positivity (PD) was assumed to reflect attentional suppression. Our findings suggest that the salient-but-irrelevant distractor wins the initial competition for selection when nontargets match the attentional template for the target and perceptual ambiguity is therefore high. In contrast, when the nontargets were a poor match to the attentional template, the salient element could be suppressed. Our study is important with respect to recent claims that saliency signals are suppressed when they are irrelevant. Our results show that suppression of salient-but-irrelevant distractors is only possible when visual search is efficient and perceptual ambiguity therefore low.

53.4004 Looking for color while searching for onsets: The efficiency of top-down search sets is influenced by task context

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According to the contingent-capture theory (Folk, Remington, & Johnston, 1992), irrelevant onset cues capture attention only if the searched-for target is also defined by its onset. If the target is defined by color, onset cues should not capture attention because such cues do not match the top-down control settings to search for the target's feature (i.e. color). Yet, the corresponding evidence stems from onset cues of a target-similar color. Such onset cues potentially match to two control settings: one for onsets and one for color. As a consequence, a match of the cue color to the control settings could have contributed to attention capture by onset cues, or might even explain it. In a series of experiments, we tested this possibility and found stronger attention capture by onset cues with a target-similar color than by onset cues with a target-dissimilar color when search was for onset targets. In addition, we found attention capture by target-similar color cues, but not by target-dissimilar color cues during search for onset targets. Based on these and related findings, we conclude that color-based contributions to top-down contingent attention capture by onset cues is due to the participants' context-dependent use of the most efficient control settings.

53.4005 Is prefrontal cortex susceptible to odd visual stimuli?

Seiichiro Naito[1](snaito@keyaki.cc.u-tokai.ac.jp), Eimi Asakura[1]; [1]Human and Information Science Tokai University

Purpose: We investigate the susceptibility of the prefrontal cortex to the odd visual stimuli measuring hemodynamic response. The subject observes the Motion Induced Blindness (MIB), which is odd enough to attract one's attention. We search the locus where the hemodynamic response is detectable. We study issues such that the response is transient or sustained and that the neurovascular coupling is oxygenated or deoxygenated. Method: We utilized Near InfraRed HemoEncephaloGraphy (NIR HEG). Preliminarily, different length of time sessions were examined. The attentional response was transient. For reliable HEG response, one second or more period was needed. The stimulus condition therefore was that the target figure disappeared by MIB effects for 500ms. The next 500ms had no MIB. The episode repeated 5 times. For the control condition, the similar stimulus was presented without MIB. The subject observed 5 second control, i.e. without MIB, episode then observed 5 second MIB episode. The 10 second episode composed a single session. A short break was taken at the disposal of the subject. He repeated the session. By trial and error, we searched the measurement site where HEG ratio difference was detectable. We obtained a couple of reliable data by the intensive search. Results: At Brodmann 10, where the light source was on the sinus and the light detector was 3cm horizontally apart to the right hemisphere, the HEG ratio was high for MIB and low for the control conditions. Discussion: At right Brodmann 46, we found that for MIB period HEG ratio was low. If we accept neurovascular coupling hypothesis, whether the light detector was close to artery or to vein determines the increase or decrease of HEG ratio Conclusions: We found a few seconds transient hemodynamics responding to the odd visual stimuli. HEG ratio not necessarily increased but also decreased.

53.4006 A novel singleton color captures attention on a surprise trial

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While it is common wisdom that a salient visual event draws attention, experimental research provided only mixed support for this hypothesis. The present experiment seeks evidence that a singleton draws attention to the degree that its feature is novel or unexpected. To test this proposition, an irrelevant singleton paradigm is used where a salient singleton that is uncorrelated with the target position is presented on each trial to familiarize participants with the presence of the singleton. On the critical trial, the singleton was presented in a novel color for the first time and without prior announcement. The singleton was gazed at significantly earlier and longer in the critical trial, as compared to the pre-critical trials. This result is consistent with predictions from the expectancy discrepancy hypothesis that color-novelty is sufficient to capture attention.

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53.4007 Reliability of eye movements and reaction times measuring attention capture

Hanna Weichselbaum[1](hanna.weichselbaum@univie.ac.at), Christoph Huber-Huber[1], Ulrich Ansorge[1]; [1]University of Vienna, Austria

Visual attention can be captured either in a bottom-up way by the properties of an object, or in a top-down manner depending on the goal of the observer. Such attention capture has been shown by a large amount of research using mostly reaction time measurements of manual responses but also eye movement parameters. Despite this, little is known about an individual's temporal stability or reliability of such effects. In order to analyze reliability of bottom-up versus top-down attention capture, we used a visual search paradigm. Participants had to search for a color-defined target and report a stimulus inside the target. Top-down matching distractors had the same color as the searched-for target; non-matching distractors had a different color than the target. In addition, we used trials with a color-singleton target and no distractor. Bottom-up capture was reflected in a difference between trials with a non-matching distractor and trials without a distractor. Top-down capture was reflected in a difference between trials with a matching distractor and trials with a non-matching distractor. Manual reaction times and target fixation latencies were fastest for trials without a distractor and slowest for trials with a matching distractor, with a significant difference between matching-distractor and non-matching-distractor trials. Furthermore, repeatedly measuring both bottom-up and top-down attention capture effects in two successive sessions (one or four weeks apart) suggests that both effects are stable across time.

53.4008 Do Different Attention Capture Paradigms Measure Different Types of Capture?

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Why do certain objects capture our attention? Some researchers propose that attention capture is largely the result of a match between stimulus features and our current goals (top-down view), while others maintain that capture is primarily determined by stimulus salience (bottom-up view). The present research focused on understanding the interrelationships between capture in four classic attention capture paradigms used to support top-down and bottom-up views of attention capture. Classic capture effects were replicated across all four paradigms, after which alternative models of attention capture were compared (attention capture as a unitary construct vs. top-down and bottom-up as separate latent factors). In general, tasks traditionally thought to tap top-down and bottom-up forms of capture did not relate in expected ways. Capture measured in each task may instead be related to specific task demands and strategies rather than broad categories of attentional control such as top-down and bottom-up. Exploratory factor analysis suggested that bottom-up capture by onsets and color singletons might represent distinct phenomena. In general, the correlations among capture scores derived from these paradigms, measures of capture reliability, and the distributions of capture scores revealed that there is still much to explore regarding attentional control even in these relatively simple laboratory paradigms.

53.4009 **Attentional capture by non-biologically relevant stimuli: an illustration with car stimuli** Ana Júlia Moreira[1,2](ana.fernandes-moreira@etu.univ-lille3.fr), Nathalie Herbeth[2], Nathalie Le Hir[2], Laurent Sparrow[1]; [1]Université de Lille, SCA Lab UMR 9193, Lille, France, [2]Groupe Renault, Guyancourt, France

Studies based on reaction time have shown that highly relevant stimuli (threatening, important to survival) have a facilitating effect on the attentional system (Brosch, Sander, & Scherer, 2007; Lipp & Derakshan, 2005). Saccadic velocity is related to the activation state in visual performance tasks (App & Debus, 1998), with peak velocity being the most sensitive parameter of the saccadic main sequence regarding attentional state variations (Di Stasi, Marchitto, Antolí, & Cañas, 2013). The goal of this study was to evaluate whether non-biologically relevant and familiar stimuli, such as car exteriors, could also evoke a significant attentional capture. Cars were divided in two types: concept (C; innovative design; non-commercialized cars) and non-concept (NC; commercialized cars), as studies have already shown that more innovative designs are cognitively more demanding (Carbon, Hutzler, & Minge, 2006). In a dot probe task, two cars were shown simultaneously for 500ms, followed by a dot, with participants having to push a button depending on which side the dot appeared on. In total, 55 colorless pictures, and with 3x3cm dimensions were presented. Participants were shown three lists: list 1 (NC and C cars mixed; 18 car pairs), and lists 2 and 3 (NC and C cars separately; 17 and 9 pairs respectively). Reaction times, electrodermal activity and eye movements were recorded. A questionnaire regarding exterior car appreciation was also administered. NC cars elicited higher mean electrodermal response and saccadic peak velocity than C cars. The lack of reaction time results shows that car exteriors are not biologically relevant stimuli. However, they are still important enough to evoke an attentional capture, which is sustained by significant electrodermal response and saccadic peak velocity results. An exploratory analysis also revealed significant differences regarding different car shapes.

53.4010 **Object contextual knowledge alters visual attention** Wei Chen[1](emma.chen.w@nyu.edu), Olivia Cheung[1]; [1]Objects and Knowledge Laboratory, New York University Abu Dhabi, PO Box 129188, Abu Dhabi, United Arab Emirates

Contextual knowledge has been shown to facilitate object recognition. A recent study suggested that contextual integration of individual objects requires attention (Gronau & Shachar, 2014). In contrast, attention also appears to be influenced by semantic information within a real-world scene context (Hwang et al., 2011). Currently, it is unclear whether object contextual knowledge is activated when object identity information is completely task-irrelevant. To investigate whether task-irrelevant contextual information may influence attention allocation, we measured eye movements in a simple 3-object display. Participants (N=25) were first asked to fixate at the object presented at the center of the screen, with two peripheral objects presented on each side (the objects were 4˚ in size and the peripheral objects were 8˚ apart from the center object). In each object triplet, the peripheral objects were either contextually related or unrelated to the center object (e.g., a grater - center, cheese and a backpack - peripheral). After a brief delay (375-475ms), a color probe would appear on one of the peripheral objects and participants were asked to make a saccadic response as quickly as possible. While contextual information was task-irrelevant, we observed the influences of contextual relatedness depending on the stimulus onset asynchrony (SOA) between the presentation of the object array and the probe. With shorter SOA (< 425ms), faster saccadic responses were found for related compared to unrelated items, whereas the opposite was found with longer SOA (>425ms). These results reveal a dynamic effect of contextual knowledge on visual attention: related objects appear to be prioritized and capture attention at an early stage, compared to unrelated objects. Interestingly, the advantage for related objects does not last and attention is then shifted to unrelated objects. Our finding is consistent with the idea that high-level representation, in this case contextual information, can influence attention allocation.

53.4011 **Task-irrelevant contextual expectation impairs orientation discrimination performance** Nuttida Rungratsameetaweemana[1](n-rungrat@ucsd.edu), Sirawaj Itthipuripat[1], John Serences[1, 2]; [1]Neuroscience Graduate Program, [2]Department of Psychology, University of California, San Diego

Expectations play a critical role in guiding vision during everyday life. In some cases, expectation is directly relevant to the currently relevant stimulus, while in other cases, expectation is not directly relevant but is instead tied to some other contextual aspect of the task (termed contextual expectation). Information about what target features are relevant (e.g., target orientation and location) has been shown to improve visual discrimination by enhancing the efficiency of sensory processing. However, less is known about how task-irrelevant contextual performance are similar to those induced by information about task relevance. Here, we presented subjects with a bilateral visual display of square-shaped and circle-shaped cues; these cues were presented 0-450ms before a bilateral stimulus array containing a horizontal (non-target) or a slightly tilted vertical grating (target). Task-irrelevant contextual expectation was manipulated by changing the relationship between the color of the left and right cues (e.g., in 70% of trials, left and right cue were presented in red and blue respectively, while in 30% of trials the left and right cue were presetned in blue and red respectively). We found that information about target location increased behavioral performance by reducing reaction times, specifically when the target array appeared 50-450ms after cue onset. In contrast, contextual expectation only had an effect on accuracy at the 0ms cue-to-target onset asynchrony such that an ‘unexpected' context increased discrimination accuracy. Taken together, these results suggest that task-irrelevant contextual expectation and task-relevant information can have opposing effects on perceptual performance with distinct temporal dynamics.

53.4012 **Episodic Long-Term Memories Capture Attention Disproportionately in the Presence of Retrieval Cues** Allison Nickel[1](aenickel@uwm.edu), Lauren Hopkins[1], Deborah Hannula[1]; [1]University of Wisconsin, Milwaukee

Attention capture by perceptually salient items and by distractors that have affective value has been reported in the literature. Whether, and under what circumstances, affectively neutral materials, encoded into long-term memory (LTM) might also be subject to attentional prioritization remains relatively unexplored. To address this gap in the literature, participants who completed the current investigation encoded 36 scene-object pairs prior to completing a basic attention task; the objects were simple colored circles. During attention task performance, eye movements were recorded as participants were presented with multiple object displays. Upon presentation of each display, participants were instructed to immediately fixate a target object (e.g. a square), ignoring all of the remaining display elements (i.e. colored circles). Attention task displays were of three types. Baseline trials consisted of 6 objects, none seen during the corresponding encoding phase. No Cue trials consisted of 6 objects, one of which had been studied. Cue trials were preceded by the presentation of a studied scene, and consisted of 6 objects, one of which was the studied associate of the scene cue. It was expected that capture would be greatest following scene cues, which were expected to trigger retrieval and active representation of the associated object. Consistent with this prediction, results indicated that saccades to irrelevant distractors (i.e. encoded and to-be-ignored objects) occurred more often in the presence of scene cues. Furthermore, saccades that went directly to targets, as instructed, were initiated more slowly in the cue condition than in no cue and baseline conditions; differences in saccade initiation time to no cue and baseline trials were not significant. Collectively, these results indicate that long-term memories can capture attention, but that this outcome may be limited to situations in which the memory representation has been recovered and is active prior to presentation of the corresponding attention displays.

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53.4013 **Can visual working memory capture result in long-term memory representations of irrelevant features?** Rebecca Goldstein[1](rgolds5@lsu.edu), W. Joseph Delaune[1], Melissa Beck[1]; [1]Louisiana State University

The contents of visual working memory (VWM) can capture attention during visual search (Dowd & Mitroff, 2013) and a consistent target can lead to a long-term memory (LTM) representation that can capture attention (Carlisle et al, 2011). Can information attended during VWM capture lead to a LTM representation that can capture attention? Participants completed 70 training trials in which a colored shape was held in VWM while searching for a rotated N among upright Ns. All search items were placed on top of larger colored shapes, and one of the distractors was on a colored shape that matched the color, but not the shape, of the VWM item. Although the color of the VWM item changed on each trial, the shape of

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the VWM color matched distractor was the same on every training trial. To test if the consistent shape of the color matched distractor was learned and could affect search, 15 test trials were completed in which the consistent shape was present as a distractor, but was not the same color as the item in VWM (no color match). The remaining 15 test trials were the same as the training trials (color match). The consistent distractor was fixated faster in the color match compared to the no color match test trials. Furthermore, the consistent shape distractor was fixated more often and longer than a random distractor in the color match, but not the no color match, test trials. These results demonstrate that the contents of VWM capture attention, but the shape associated with the attended color does not lead to a LTM representation that captures attention. This may be due to the lack of bound shape-color representations in VWM, and different results may be found with features that are more readily bound (e.g., color and location).

53.4014 **Active visual working memory representations are insufficient to control spatial attentional capture.** Blaire Dube[1](bdube@uoguelph.ca), Krista Miller[1], Maria Giammarco[1], Naseem Al-Aidroos[1]; [1]Department of Psychology, University of Guelph

When an item is held active in visual working memory (VWM), visually similar information in the environment will capture attention, even if it is task-irrelevant. This capture is commonly measured through the modulation of visual-search distractor costs. Memory-matching distractors slow response times more than unrelated distractors, suggesting that placing an item in VWM is equivalent to establishing an attentional control set (ACS) for that item's features. Here we examined this possibility by testing a different prediction of ACSs: Beyond facilitating capture by matching stimuli, ACSs should eliminate capture by non-matching stimuli, at least when measured using spatial cueing effects (i.e., response time differences when a task-irrelevant cue is presented at the target location versus a non-target location). In contrast to this control over cueing effects, establishing an ACS does not eliminate the cost of non-matching search distractors, ostensibly because distractor costs measure an additional "non-spatial" component of capture. Across two experiments, participants completed a cued visual-search task while maintaining a color in VWM. The task-irrelevant cue stimulus could either match the color of the VWM item or not, and could appear at the target location (cued trial), a non-target location (un-cued trial), or not at all (no-cue trial), allowing us to measure both spatial cueing effects (cued vs. un-cued) and search distractor costs (un-cued vs. no cue). Consistent with previous search tasks, all cues produced distractor costs, and these costs were larger for memory-matching stimuli. Cueing effects by non-matching stimuli were not eliminated, however. In fact, both matching and non-matching cues produced robust cueing effects, with little evidence for VWM-based modulation. By showing that VWM-based guidance does not prevent non-matching stimuli from capturing spatial attention, these findings extend recent proposals that adopting an ACS requires more than the storage of information in VWM.

53.4015 **Attentional disengagement suppresses visual long-term memory** Yoolim Hong[1](hong.503@osu.edu), Andrew Leber[1]; [1]Department of Psychology, The Ohio State University

When a salient, task-irrelevant stimulus captures attention, we must disengage from it to resume goal-directed behavior. How is disengagement achieved? Several theories postulate that suppression of the distractor is necessary, although viable alternatives have been proposed. Here, we introduce a novel test for disengagement-related suppression, using a subsequent memory design. In Phase 1 (Incidental Memory Encoding), participants categorized a series of objects as living or non-living. In Phase 2 (Visual Search), participants searched for an oddball shape target while trying to ignore a salient color singleton. Critically, we placed an object from Phase 1 inside the color singleton; our goal was to assess how distractor disengagement would affect the memory representations of these objects. Based on intertrial priming studies, we anticipated that the salient distractors would elicit greater attention capture – and, consequently, more distractor disengagement – on trials in which the target switched vs. repeated its shape (compared to the previous trial). Thus, we could examine the effects of greater vs. lesser disengagement on objects that appeared during target switch vs. repeat trials. In Phase 3 (Surprise Perception/Memory Test), on each trial, participants were first shown a new or old object (from Phase 1), superimposed with a salt and pepper noise mask. We asked participants to gradually reduce the noise until they could identify the object, enabling us to assess its perceptual representation on a continuous scale. After identification, the object was fully unmasked, and participants then judged if it was new or old. If suppression accompanied distractor disengagement during Phase 2, then both perceptual identification and subsequent memory for the objects inside the distractor would be degraded. Indeed, results showed worse perceptual identification and recognition memory for items presented during Phase 2 target switches compared to target repetitions. We conclude that distractor disengagement is an inherently suppressive process.

53.4016 **Don't Let It Distract You: Availability of Reward Affects Attentional Selection** Michel Failing[1](michel.failing@vu.nl), Jan Theeuwes[1]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam

Recent studies have shown that reward contingencies affect attentional selection. Stimuli that were selected and previously rewarded continue to capture attention even if the reward contingencies are no longer in place. In the current series of experiments, we investigated whether task-irrelevant and non-salient stimuli that merely signal the magnitude of reward available on a particular trial affect attentional selection. Crucially, in these experiments, attentional selection of the reward-signaling stimuli was never necessary but instead detrimental for actual payout. Participants searched for a target (in different experiments for either a specific color or shape) presented among five distractors. The color of one of the distractors signaled the reward available for that trial (e.g. a red distractor would indicate a high reward, a green distractor a low reward). Even though this colored distractor signaling reward availability was never part of the task set, nor physically salient, it captured attention. Follow-up experiments suggested that stimuli signaling reward get prioritized for attentional selection through reward-learning. However, this learning did not occur for participants who were not informed about the stimulus-reward association or for participants who did not become aware of the association themselves. We conclude that task-irrelevant and non-salient stimuli signaling the availability of reward gain priority in attentional selection even if selecting them is not necessary but rather detrimental for reward payout. Importantly, our data suggest that reward-signaling stimuli only capture attention once they have initially been prioritized for attentional selection. Such initial prioritization can occur through knowledge or task-relevance of the reward-associated stimuli or by rendering them perceptually salient. After the initial prioritization, learned stimulus-reward associations continue to bias attentional selection toward the reward-signaling stimuli independently of top-down or bottom-up processes, whether their selection is beneficial for reward payout or not.

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53.4017 **Do high-reward distractors capture attention? It is all about the context!** Tobias Feldmann-Wüstefeld[1,2](tobias.fw@gmail.com), Ruben Brandhofer[1], Anna Schubö[1]; [1]Philipps-University Marburg, [2]University of Chicago

Various studies have shown that reward has a strong impact on attention deployment in visual search tasks; features associated with high reward are more likely attended in subsequent trials than features associated with low reward. The present study focussed on the role that reward plays for the processing of irrelevant distractors. We used a visual search task in which additional singletons (salient distractors) were associated with high or low rewards throughout the task and investigated which neural mechanisms (target enhancement / distractor suppression) are responsible for prioritized processing of distrators associated with reward. To that end, we used sub-components of the N2pc in the event-related EEG: the NT (target negativity) and ND/PD (distractor negativity/positivity). We also varied the context homogeneity in order to render visual search more (heterogeneous) or less (homogeneous) prone to disruption from a non-target color singleton. Participants were given a monetary reward contingent on the color of the distractor after each trial. High-reward distractors delayed responses in heterogenous contexts, but not in homogenous contexts.For both heterogeneous and homogeneous contexts, the NT, indicative of attention deployment to the target, was smaller when the target was presented together with a high-reward distractor, indicating that high-reward distractors interfere with target enhancement, regardless of context. In heterogeneous contexts, high-reward distractors elicited a larger ND component, indicating greater attentional capture, and a larger PD component, indicating more effort to suppress distractors. In homogenous contexts, ND and PD were not modulated by reward, suggesting no reward-related differences in attentional capture or suppression. In sum, the results showed that distractor suppression is only affected by reward if the context makes visual search vulnerable to attentional capture. Target enhancement, however, is always disrupted by a high-reward distractor, regardless the context.

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53.4018 **Contingency Awareness is not required for Fear Conditioned Capture of Attention** Lauren Hopkins[1](lhopkins@uwm.edu), Nicholas Christopher-Hayes[1], Fred Helmstetter[1], Deborah Hannula[1]; [1]University of Wisconsin-Milwaukee

Past work has shown that fear conditioned materials can capture attention, but under most circumstances participants have explicit knowledge of the contingent relationship. One concern is that this explicit knowledge may lead to voluntary prioritization of the conditioned stimulus despite instructions otherwise. The current study used a probabilistic fear conditioning paradigm in conjunction with eye tracking to address questions about whether or not predictors of shock capture attention in the absence of explicit awareness. Participants completed a training phase followed by a test phase. During training, eye movements were recorded as participants located a red or green circle embedded in an array of distractors (i.e. additional colored circles). They were told that if they were too slow to find the target they would receive a shock. In reality, one color (e.g. red, the CS+) was paired more often with shock delivery than the other (e.g. green, the CS-) regardless of the participant's behavior. During the subsequent test phase, participants were instructed to fixate a uniquely shaped item (e.g. diamond) among distractors (e.g. a variety of colored circles). Test trials were of three types and were either missing a CS (i.e. baseline trials), included the CS+, or included the CS- in the array. Importantly, the CS+ and the CS- were never targets and were task-irrelevant. Objective and subjective questionnaires sensitive to awareness of the contingencies imposed during training were completed after the experiment. . Despite instructions to ignore distractors, and poor contingency knowledge, participants fixated the CS+ more quickly than the CS- during training, and made erroneous saccades to the CS+ more often than the CS- during test. These results are consistent with the view that learned indicators of danger are subject to attentional prioritization and capture, effects that are evident even when participants cannot articulate or identify the learned associations.

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Attention: Priming, cueing, guiding, and dividing

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

53.4019 **Explaining the action effect** Greg Huffman[1](greg.huffman@mail.utoronto.ca), Jay Pratt[1]; [1]University of Toronto

Consider a paradigm in which a visual stimulus is first presented and then a feature of that stimulus appears as either a target or distractor in a subsequent visual search task. It has been shown that if a response is made to the initial appearance of the stimulus, a validity effect is found; search times are faster when the stimulus is part of a target than when it is part of a distractor. This validity effect disappears if a response is withheld to the initial stimulus. Our study demonstrates that there is a validity effect and an inverse validity effect. First, like previous studies, we replicated the validity effect when the first stimulus was responded to. Second, unlike previous studies, when the first stimulus was not responded to, in four experiments we consistently observed an inverse validity effect such that faster search times occurred when the initial stimulus was contained in a distractor. Third, when we changed the second task from a visual search to stimulus presented in isolation, only the inverse validity effect was found. Fourth, when we increased the overlap between the first and second response buttons, the inverse validity effect increased. Based on our findings, we argue that the validity effect is driven by biased competition; responding to the first stimulus increases the attentional weights assigned to that stimulus's features such that it wins the competition for selection in the search phase. The inverse validity effect, however, is driven by feature binding into event files as there is a partial repetition of the event file formed from the first response when responding to the search event.

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53.4020 **Arousing Brute Force and Alerting Selectivity** Árni Ásgeirsson[1](arnigunnarasgeirsson@gmail.com), Sander Nieuwenhuis[1]; [1]Cognitive Psychology Unit, Faculty of Social Sciences, Leiden University

Arousal is an important modulator of diverse behavior, and has been shown to alter performance in various tasks, most notably those requiring a high level of cognitive control. Less is known about the effects of arousal on feature selectivity in visual attention. Both recent and classical theories have hypothesized that increased arousal narrows the scope of attention, resulting in facilitated processing of physically, or behaviorally, salient stimuli. We used 4 different arousal manipulations, in otherwise identical experiments, to test the effects of arousal upon feature selectivity. Observers were presented with a red target letter in brief post-masked displays. Distractor letters (blue or yellow) were presented alongside the target on some trials, to vary the degree of feature selectivity required of observers. Arousal was manipulated using loud white noise, emotionally arousing images, an alerting tone (300 ms tone-to-target SOA), or an accessory stimulus tone (30 ms SOA). Race models were fitted to the results of each experiment to assess which components of attention were affected by arousal. Our results demonstrate that 1) white noise did not affect attention, while 2) phasic arousal by emotional image presentation did increase the overall processing capacity of observers, without any benefits to selectivity. 3) The accessory stimulus had a large increase in processing capacity, but reduced feature selectivity. 4) Conversely, when the alerting tone was presented there was no change in overall processing capacity, but selectivity was facilitated to an extent that rendered the distractors functionally inept. Our models suggest that the brief presence of a loud tone triggers an immediate and transient increase in indiscriminate processing, followed by a period of almost perfect selectivity, and highlight the importance of constraining experimental designs to reveal the cognitive processes that are affected by arousal.

53.4021 **Interference Control in Adolescents with ADHD - A Different Point of View** Orly Azulai[1](orli.azulai@gmail.com), Carmel Mevorach[2], Lilach Shalev[1,3]; [1]School of Education, Tel Aviv University, Israel, [2]School of Psychology, University of Birmingham, UK, [3] The Sagol School of Neuroscience, Tel Aviv University, Israel

Previous studies investigating inhibition have typically engaged the classic Stroop color-word paradigm. Stroop interference is a phenomenon that depends, in part, on an asymmetry in baseline discriminability between two stimulus dimensions. This asymmetric pattern leads to an increased difficulty to handle conflicting responses when the more discriminable dimension serves as the distractor and the less discriminable dimension serves as the target (that is, a high conflict task), but not vice versa (that is, a low conflict task) (Stroop, 1935). In the context of Attention Deficit/Hyperactivity Disorder (ADHD), Stroop studies indicated mixed results as to the interference impairment. To further investigate the locus of response conflict impairment in ADHD we used a non-verbal Stroop-like task with a group (n=49) of adolescents with ADHD as well as a control group (n=49). The Stroop-like task measures the efficiency of filtering distracting information, and induces the asymmetry mentioned above by incorporating either a low conflict sub-task (location judgment) or a high conflict sub-task (direction judgment). The ADHD group was overall less efficient than the control, yet for both groups we found a mismatching discriminability in favor of location judgments. However, this asymmetry translated into a stronger interference effect when this dimension had to be ignored only for the controls. In contrast, the ADHD group showed comparable interference for both location and direction judgments. The fact that in the ADHD group the interference effect was not influenced by whether the irrelevant information was more or less discriminable than the relevant information may reflect an impairment in the ability to suppress irrelevant information regardless of its discriminability.

53.4022 **Visual attention around invisible hands** Satoshi Shioiri[1,2](shioiri@riec.tohoku.ac.jp), Ryota Nishikawa[2], Kazumichi Matsumiya[1,2], Ichiro Kuriki[1,2]; [1]Research Institute of Electrical Communication, Tohoku University, [2]Graduate School of Information Sciences, Tohoku University

[Purpose] We investigated attentional facilitation around the observer's hand, which was hidden from the eye, using flash lag effect (FLE). The FLE is known to be reduced by attention and can be used as the index of attention. [Method] We compared the FLE of the stimulus presented either in the left or right of the fixation with various hand conditions: either left or right hand was positioned at left or right stimulus location. Visual stimulus was seen through a mirror, which covered the observer's hand, and the position of the invisible hand was arranged to be right above the stimulus. White disk with a red bar rotating on it was presented at each stimulus location. A red dot was presented near each end of the rotating bar on either of the disks at unpredictable timing. The observer was instructed to memorize the relative location of the dots and rotating bar. The relative location was reproduced after the trial and recoded as the FLE. There were two attentional conditions. In one condition, the disk with flash was informed before each trial (Single condition) and it was not in the other condition (Double condition). We also measured EEG, and analyzed SSVEP to the disks and ERP to the flash presentations. [Results] The flash presented near the hand resulted larger FLE, comparing with the flash far from the hand. Hand effect was similar for the Single and Double conditions while the FLE was smaller in the Single condition due to the endogenous attention. That is, the attentional effect was increased near the hand even at the location where the observer asked to attend. This attentional effect near the hand was supported by both SSVEP and ERP responses. We conclude that there is attention around the hand, which is attracted automatically by hand.

53.4023 **Evidence for the Redundant Signals Effect in Detection of Categorical Targets** Ada Mishler[1](ada_mishler@knights.ucf.edu), Mark Neider[1]; [1]Psychology Department, College of Sciences, University of Central Florida

The redundant signals effect is characterized by shorter response times (RT) when two targets are present than when only one target is present. Previous work on the redundant signals effect has employed specific targets; for example, participants might be asked to press a button every time they see the number "2." The purpose of the current study was to determine whether or not the redundant signals effect extends to categorical targets; for example, asking participants to press a button every time they see any number. Toward that end, participants performed a go/no-go task in which they pressed a button every time they saw a number on a computer screen. Each trial contained two stimuli subtending 1º by 1º visual angle and placed 3º above and below the center of the display. On 50% of the trials, both stimuli were letters (no-target condition). On 25% of the trials, one stimulus was a letter and one stimulus was a number (one-target condition), and on 25% of the trials, both stimuli were numbers (redundant-targets condition). Accuracy did not significantly differ between the redundant-targets (almost 100% accuracy) and single-target conditions (~99% accuracy, $p = .165$). RT was faster in the redundant-targets condition (~461 ms) than in the single-target condition (~509 ms, $p < .001$). The results indicate that the redundant signals effect occurs even when participants search for a category of targets. Previous studies have suggested that redundant signals can increase the speed of early visual processing; our findings suggest that redundant signals can also increase the speed of processing at the categorical level.

53.4024 **Dual Task Costs in Surround Motion Integration** Jessica Cali[1](calij@mcmaster.ca), Jiali Song[1], Allison Sekuler[1], Patrick Bennett[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University

In a traditional dual-task paradigm, performance typically suffers in both tasks compared to performance on either task alone. However, paradigms in which dual task performance exceeds single task performance have gained a lot of attention in recent years. In one such example, Motoyoshi et al. (2014), found dual-task enhancement in a direction discrimination task that used Random Dot Kinematograms (RDKs) when a digit-identification RSVP task was administered simultaneously. They attributed this finding to a reduction of surround suppression that was caused by performing the dual task. We sought to replicate this finding. We used a staircase procedure to measure dot coherence thresholds in three conditions: 1) RDK with simultaneous RSVP stream, where participants reported the two numbers in the RSVP stream and then reported RDK direction; 2) RDK with simultaneous ignored RSVP stream, where participants reported only RDK direction; and 3) RDK presented alone, where participants reported the direction of the RDK. The first two conditions were similar to those used by Motoyoshi et al. (2014); condition 3 was added to determine the impact of including an ignored, centrally-fixated RSVP stream. Each participant completed all three conditions in a randomized order. In contrast to the pattern of results found by Motoyoshi and colleagues, coherence thresholds in the dual-task condition were significantly higher than the two single task conditions (which did not significantly differ from one another).The reasons for the contradictory findings are unclear, but our findings suggest that it may be premature to conclude that sensitivity to RDK direction is enhanced by dividing attention between two tasks.

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53.4025 **The Effects of Foveal Versus Auditory Working Memory Dual-Task Loads on Covert and Overt Attention** Ryan Ringer[1](rvringer@ksu.edu), Zac Throneburg[1], Aaron Johnson[2], Arthur Kramer[3], Lester Loschky[1]; [1]Department of Psychological Sciences, Kansas State University, [2]Department of Psychology, Concordia University, [3]Beckman Institute, University of Illinois, Urbana-Champaign

How do overt and covert attentional breadth extend over visual space at a given point time? Williams (1988, 1989) argued that for covert attention, "tunnel vision" requires a foveal load, while other attentional manipulations produce general interference (Crundall, Underwood, & Chapman, 2002). Nevertheless, several studies have shown that auditory loads cause tunneling of overt attention (e.g., Reimer et al, 2009; Greene et al., 2012). Previously, we reported two experiments where participants discriminated m-scaled, gaze-contingently presented Gabor patches at 0, 3, 6, or 9 degrees eccentricity. Attention was manipulated in dual-task conditions with either a foveal (rotated L/T discrimination) or auditory working memory (n-back) load (Ringer, et al., 2015). The foveal load produced tunnel vision whereas the auditory WM load produced general interference, demonstrating that a foveal bias is necessary to produce tunneling of covert attention. Here, we ask whether these load-dependent effects on covert attention translate into similar effects in overt attention, particularly when fixed visual limitations (i.e., cortical magnification) have been controlled for. To answer this question, we analyzed the length of saccades immediately following a Gabor presentation in dual versus single-task conditions of our previous auditory WM (N-back) and foveal (L/T discrimination) load experiments. Overall, the saccade lengths between auditory and foveal loads were quite similar, however the saccade lengths for auditory loads were slightly smaller than for the foveal load. This was surprising, since the foveal load produced greater covert attention decrements than the auditory WM load. However, when comparing the interaction between task and eccentricity (indicative of tunnel vision), there was a greater divergence between single versus dual-task saccade lengths for the foveal load. Thus, both our previously reported results for covert attention (Ringer, et al., 2015) and the currently reported results for overt attention are consistent in showing tunnel vision only with a foveal load.

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53.4026 **Associative activation and its relation to mental exploration** Shira Baror[1](baror.shira@gmail.com), Moshe Bar[1]; [1]Gonda Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel

The tension between exploration and exploitation affects behavior as well as how we attend and perceive the world around us. The goal of the current research was to examine whether this tension also influences internal mental operations such as basic associative activation. We hypothesized that associative activation is not only determined by associative strength, as suggested by the traditional account of spreading activation, but also by the proclivity to cognitively explore or to exploit. In a series of studies, we manipulated participants' predisposition with respect to the exploration-exploitation continuum by controlling the availability of resources, while asking them to respond to free association tasks. The likelihood to provide consensual (strong) or unique (remote) associations was measured, as well as their reaction times. According to our hypothesis, if internal associative processes are determined by exploration vs. exploitation bias, which is dictated by the availability of resources, high load will result in a more automatic activation of immediate associations, whereas low load will be more conducive of an exploratory state manifested by more original free associations. In agreement with this hypothesis, we found that for both cognitive and perceptual load manipulations, higher load levels consistently led to a narrower scope in associative responses and to lower variability across subjects. A comparison between the effect of load on associative activation with words and with visual objects will be made in this context. These findings demonstrate that while in conditions akin to exploitation (high load) associative processes rely more heavily on strong and consensual associations, in conditions analogous to exploration (low load), distinct associations are significantly favored. It is implied that the access to associations is state-dependent. These findings also have potentially important implications to understanding pathologies in associative processes, such as mood disorders, on the one hand, and creativity on the other.

53.4027 **Stroop together: No evidence for shared representations of response-set in conflict resolution** Wieske van Zoest[1](wieske.vanzoest@unitn.it), Daniel Saunders[1], David Melcher[1]; [1]Center for Mind/Brain Sciences, University of Trento, Italy

Mechanisms underlying the ability to perform joint actions can lead to shared task representations between people working in a shared space, even when the tasks are independent. The present study investigated whether shared representations influence the inhibition of irrelevant information and modulate conflict resolution in the color-word Stroop task. If so, we expect greater interference from an incongruent word that is part of the partner's response-set relative to an incongruent neutral word, comparable to the effect of one's own response-set. The task was performed together with another participant (Experiment 1) or alone (Experiment 2 and 3). Participants were instructed to respond to two colors (e.g., response-set red and green). Two other colors were presented (e.g., yellow and blue) and in Experiment 1 these were assigned to the partner. This combination of events created two critical incongruent conditions where the incongruent word was part of 1) one's own response-set (e.g. 'red' in green pixels) or 2) the partner's response-set (e.g., 'yellow' in green pixels). There was a third incongruent neutral condition (e.g. 'pink' in green pixels) and a congruent condition ('green' in green pixels). The results of Experiment 1 showed an interference effect for both one's own and the partner's colors compared to the neutral incongruent condition. However, these interference effects were also identical when the other set of colors were assigned to "the computer" in Experiment 2 or left unassigned in Experiment 3. These non-social control experiments suggest that mere exposure to the other two colors evoked increased inhibition, even when the colors were not responded to in any way. This work provides an example of potential confounds when studying social influences, and also underscores a role for an automatic influence of distractors in the modulation of conflict resolution in Stroop tasks.

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53.4028 **The spatiotemporal neural dynamics of attentional failures during sustained dual-task performance.** James Elliott[1,2](elliott@psych.ucsb.edu), Barry Giesbrecht[1,2]; [1]Department of Psychological and Brain Sciences, UCSB, [2]Institute for Collaborative Biotechnologies

Sustaining attention over prolonged periods of time is a critical task frequently demanded by our environment. Whether while driving a car or while scanning luggage, failures to detect relevant information can be life threatening. These failures could have multiple underlying sources. To investigate the temporal and spatial characteristics of neural activity underlying these failures, 13 participants performed a continuous temporal expectancy task while simultaneously recording both EEG and fMRI. Each participant completed two tasks. In both tasks, participants monitored a stream of flickering faces and cars (15Hz) for 3.5 minutes. Standard images were presented for 800 ms while targets, requiring a face vs. car discrimination, were presented for 1100 ms. Auditory stimuli (vowel or consonant) were presented, half of which coincided with the presentation of a visual target. In the single task blocks participants only responded to the visual targets, however in the dual task blocks participants responded to both auditory and visual targets. Visual target detection accuracy was better in the single task condition (M=.51) than in the dual task condition (M=.39, $F(1,12)=10.8$, $p < .01$). There was an overall decline in performance as a function of time within each block ($F(8,96)=44.9$, $p< .001$). Analysis of the EEG data revealed an increase in occipital alpha activity in the 4 seconds preceding a missed visual target, compared to the 4 seconds preceding a target that was correctly identified (mean difference=.56 $\mu V2$, $F(1,12)=10.4$, $p< .001$). Analysis of the fMRI data revealed that correctly identified targets evoked an increase in activity in dorsal attentional control regions (anterior cingulate cortex, bi-lateral IPS) whereas missed targets corresponded with an increase in activity in the default mode network (precuneus, frontal pole, lateral parietal inferior gyri). These results reveal the underlying neural dynamics of sustained and dual task failures of performance.

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53.4029 **A gradient for the target template in feature-based attention** Hannah Wyland[1](hannah-wyland@uiowa.edu), Shaun Vecera[1]; [1]Department of Psychological and Brain Sciences, University of Iowa

Visual attention can be guided to relevant items by storing a target template in visual short-term memory (Desimone & Duncan, 1995; Wolfe, 1994). There is a great deal of evidence for the flexibility of target templates, but little work has directly investigated their precision. Contingent capture paradigms have previously demonstrated that when monitoring a central stream for a specific color, template matching peripheral distractors impair performance to a greater degree than nontarget colored distractors (Folk, Leber, & Egeth, 2002). Although these experiments suggest that attention is biased toward template matching items, the limited range of distractor colors sampled does not allow for strong conclusions regarding the template's precision. In the present series of experiments we used the logic of capture paradigms to investigate the specificity of target templates for color. In these experiments, participants monitor a grey RSVP stream at fixation for a trial-unique target colored letter and report its identity. Before the target appeared, grey distractor items (#) were simultaneously presented above, below, and on either side of the letter stream. On many trials, one of these distractors was presented in a color varying in its similarity to the target. After each trial, participants reported the target color they had just searched for to ensure that the color was stored in visual short-term memory. Our results demonstrate that participants are most captured by distractors that match their template and that there is a measurable reduction in capture as distractors become more dissimilar from the target. Our results suggest that target templates for color are relatively precise and able to minimize capture to nontarget colored distractors.

53.4030 **Limits on the contribution of priming to attentional control settings: Evidence from long-term memory control sets.** Maria Giammarco[1](agiammar@uoguelph.ca), Jackson Hryciw[1], Blaire Dube[1], Naseem Al-Aidroos[1]; [1]Psychology Department, University of Guelph

An active area in attention capture research is to understand the role of priming in establishing attentional control settings (ACSs). When participants repeatedly select target stimuli across trials of an attention task these items are primed in a bottom-up manner, which may cause attention to be preferentially captured by distracting stimuli that resemble the targets. The present work uses our recent discovery of long-term memory (LTM) ACSs to shed light on the contributions of priming. Studies evaluating priming typically have participants establish ACSs for single features or feature domains, rendering manipulations of priming dependent on changes in the ACSs across trials. This methodology confounds the contributions of priming with the potential costs of switching ACSs. The use of an LTM ACS is valuable because the ACS can consist of multiple targets, allowing participants to maintain a consistent ACS while we manipulate the amount of priming of targets within it. Across two experiments participants memorized a set of 16 (Experiment 1) or 18 (Experiment 2) images of complex, naturalistic visual objects that were then designated as targets in a rapid serial visual presentation (RSVP) task. We have previously shown that only studied items produce an attentional blink (i.e., capture attention) when they appear as distractors, suggesting participants adopt studied-item specific ACSs. In the present experiments we varied the amount of priming each target item received: frequent, infrequent, or no priming. Items that were never primed did not capture attention when presented as distractors. However, as long as items were primed, the frequency of priming (i.e., each target appeared on average every 12th trial versus 36th trial) did not affect the magnitude of capture. Together, these data reveal that although priming may support the establishment of ACSs, there are important limits to its role in the maintenance of ACSs.

53.4031 **Associative learning undermines top-down control of visual attention** Hanna Kadel[1](kadel@uni-marburg.de), Tobias Feldmann-Wüstefeld[1, 2], Anna Schubö[1]; [1]Cognitive Neuroscience of Perception and Action, Philipps University Marburg, [2]Institute for Mind and Biology, University of Chicago

In the long-standing debate on the role of bottom-up and top-down mechanisms for visual attention, the additional importance of associative learning has recently been emphasized and investigated more thoroughly. In two experiments we examined to which extent top-down mechanisms interact with an observer's individual learning experience in guiding attention. To induce associative learning, a categorization learning task was combined with an additional singleton search task in the same experimental blocks. A high degree of top-down control was enabled by presentation of advance task cues, or by complete predictability of a fixed continuous task sequence. Event-related potentials and behavioral performance measures served as indicator of attention deployment. Results showed that attention deployment during search was biased by the individual experience in the learning task: When a distractor was defined in the same dimension that observers had experienced as being predictive in the categorization learning task, it impaired visual search more strongly than when the dimension was unpredictive in the learning task. Event-related potentials indicated that the magnitude of this effect was modulated by the nature of provided top-down control. Yet, even with the highest degree of top-down control, learning effects were not entirely overruled. These results indicate that associative learning experience considerably shapes attention deployment and may significantly oppose or even undermine preparatory top-down efforts.

53.4032 **Using the texture-centroid method to analyze the mechanisms sensitive to higher-order image statistics** Kier Groulx[1](kgroulx@uci.edu), Charles Chubb[1], Jonathan Victor[2], Mary Conte[2]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Brain and Mind Research Institute, Weill Cornell Medical College

Rationale. Visual features, such as edges and corners, are carried by high-order statistics (also known as multipoint correlations or phase correlations). Analysis of discrimination of "isodipole" textures, which isolate specific kinds of high-order statistics, demonstrates visual sensitivity to these statistics but stops short of analyzing the underlying computations. Here we develop and apply a new psychophysical paradigm that gives insight into these mechanisms. Method. We focus on a canonical isodi-

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pole texture, the "even" texture -- in which any 2x2 subarray contains an even number of black and white checks. Stimuli consisted of an array of 14 texture-disks, each containing a sample of a texture drawn from the continuum from random to the pure even texture. Subjects (N=6, 1500 trials) were asked to mouse-click the centroid of the array (presented for 300 ms then masked), weighting the disks according to the evenness of the texture they contained. Performance was modeled by assuming that (1) subjects deploy a "neural filter" to derive a spatial activation map from the stimulus; (2) filter output at stimulus location (x,y) depends on the pattern within the 3x3 subblock of texture centered at (x,y); (3) the subject's estimate of the centroid is the centroid of the filter activation-map produced by the stimulus, plus response noise. Results. Subblocks whose 9 checks were all one polarity produced the highest filter-activation Asolid; subblocks comprising a single 3-check bar and six checks of opposite polarity produced an activation roughly equal to Asolid/2. All other subblocks produced activations less than Asolid/4. A 2-pass procedure showed this model accounted for nearly all of the explainable variance. Conclusions. Visual mechanisms that are sensitive to "even-ness" do not compute four-point correlations per se, but rather are activated selectively by the solid blocks and bars that occur more frequently in the even texture.

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53.4033 **Attentional competition between reach target and saccade target selection** Nina Hanning[1,2](hanning.nina@gmail.com), David Aagten-Murphy[1], Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany., [2]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, Munich, Germany.

Both eye and hand movements have been shown to draw visual attention to their goal locations during movement preparation. However, it is still a matter of debate whether a unitary attentional system underlies the selection of both eye and hand targets, or whether they are selected by independent systems. To approach this question we investigated the deployment of visual attention in coordinated eye-hand movements. In a dual movement task we asked participants to reach and look towards two different locations. The discrimination performance at the eye and hand targets was taken as a measure of the distribution of attention during motor goal selection. Our results show that attention is allocated in parallel towards both the future saccade and reach target. Importantly, the attentional benefit at the saccade target in the dual movement task was as high as in a single movement condition, in which subjects only performed an eye but no hand movement. The benefit at the reach target, however, was more pronounced in the single hand movement compared to the combined eye-hand movement condition. Thus, while attentional allocation to the saccade target was not affected by the concurrent preparation of a hand movement, the attentional benefit at the reach target suffered from the need to simultaneously prepare a saccade. Our findings indicate that action selection mechanisms for different effectors compete for attentional resources, with saccade target selection having highest priority, suggesting that targets for both eye and hand movements are represented in a unitary map of action-relevant locations.

53.4034 **Simultaneous allocation of attention to perceptual and saccade goals in a same-different matching task: Effects on discrimination and saccade performance.** Tobias Moehler[1](tobias.moehler@psychol.uni-giessen.de), Katja Fiehler[1]; [1]Experimental Psychology, Justus-Liebig-University Giessen, Germany

In the current study we investigated whether visual attention can be simultaneously allocated to spatially distinct perceptual and saccade target locations, and how the split of attention influences discrimination performance and saccade parameters (i.e., accuracy, precision, and curvature). To this end, participants performed a same-different matching task during the preparation of a saccade. A central perceptual target cue instructed participants to covertly attend to one of three possible target locations. Thereafter, a central saccade target cue instructed them to perform a saccade either to the same (congruent) or a different (incongruent) location. The discrimination task appeared after the saccade target cue, in a time range of 0 – 120 ms. In incongruent trials, in which one discrimination target appeared at the perceptual target location and one at the saccade target location, participants matched the identity of both discrimination targets (i.e., same or different). In congruent trials, only one discrimination task had to be solved at the congruent perceptual and saccade target location; participants indicated the identity of the discrimination target (i.e., E or 3). Congruent trials served as baseline. Our results show that participants' matching performance was above chance; however, perceptual performance in the single discrimination task was clearly superior. Splitting attention also resulted in altered saccade performance: saccade accuracy as well as saccade precision declined compared to baseline, and saccades curved away from the covertly attended perceptual target location. Our findings suggest that participants are able to simultaneously allocate visual attention to multiple perceptual and saccade target locations. However, orienting attention away from the saccade goal interferes with saccade programming as suggested by altered saccade performance.

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53.4035 **Task-irrelevant expectation violations in well-practiced sequential manual actions: Evidence for a "check-after-surprise" mode of visual attention and eye-hand decoupling** Rebecca Foerster[1,2](rebecca.foerster@uni-bielefeld.de), Werner Schneider[1,2]; [1]Neuro-cognitive Psychology, Bielefeld University, [2]Cluster of Excellence Cognitive Interaction Technology 'CITEC', Bielefeld University

When performing sequential manual actions on objects of the environment (e.g., making a cup of tea), visual information is prioritized according to the task determining where and when to attend, look, and act. In well-practiced sequential actions, long-term memory (LTM)-based expectations specify which action targets might be found where and when. We have previously demonstrated (Foerster & Schneider, 2015) that violations of such expectations that are task-relevant (e.g., target location change) cause a regression from a memory-based to a search-based attentional selection mode. In this study we asked how task-irrelevant expectation violations might modify attentional selection in such well-practiced sequential manual actions. This question was investigated by a computerized version of the number-connection test. Participants clicked on nine spatially-distributed numbered circles (action targets) in ascending sequence. Visual features and locations of action targets stayed constant for 65 prechange-trials, allowing to practice this simple sequential manual action. In 20 consecutive change-trials, we implemented an expectation violation in a task-irrelevant dimension, that is, action target number 4 appeared in a different font. In 15 reversion-trials, number 4 returned to the original font. During the first trial of a task-irrelevant change (font), manual clicking was slower and eye scanpaths were larger and contained more fixations. The additional fixations were mainly checking fixations on the changed target while acting on later targets. Whereas gaze was captured by the task-irrelevant change of the action target, cursor-paths remained completely unaffected. Effects lasted for 2-3 change trials and did not reappear during reversion. We conclude that a task-irrelevant expectation violation in a well-practiced sequential manual action leads to eye-hand decoupling and a "check-after-surprise" mode of attentional selection.

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53.4036 **Context matters: Driving perceptual breakthrough through contextual priming** Alexia Zoumpoulaki[1](az61@kent.ac.uk), Luise Gootjes-Dreesbach[2], Zara Bergström[3], Abdulmajeed Alsufyani[1], Howard Bowman[1,4]; [1]School of Computing, University of Kent, [2]School of Psychology & Clinical Language Sciences, University of Reading, [3]School of Psychology, University of Kent, [4]School of Psychology, University of Birmingham

A common question is whether contextual priming can influence perception through attention allocation. In the presented studies, we adapted an experiment from Arnell et al. (2007) to explore interactions of working memory and visual selection. In that experiment, they investigated what types of stimuli can capture involuntary attention. We wanted to test whether contextual priming can assist perceptual breakthrough of stimuli, which would not have been salient otherwise. In the present experiments, participants had to identify a target word (from a colour category) within an 88ms SOA RSVP (rapid serial visual presentation) stream. Before the streams, questions that prompt answers from different categories (neutral, emotionally arousing, autobiographical, episodic) were presented e.g. "What can be used to write?" Participants were told the questions were irrelevant to the identification task, but that they would at random intervals have to select the previously presented question. Within the stream, before the target, we placed either the answers to these questions or an irrelevant stimulus. We expected accuracy to the target to be impaired if the answers were presented 240ms before the target, but not 700ms before or when an irrelevant was presented. This would be in line with the attentional blink, where perceptual breakthrough of a first RSVP item impairs detection of targets appearing immediately after. The same exper-

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iment was repeated without the questions so as to test whether the critical distractors capture attention, independent of contextual priming. Our results show that adding a question can increase breakthrough in RSVP. This effect is not universal and seems to differ between categories of items, which we suggest may be explained through variables such as the extent of contextual priming (match between question and answer). As expected, intrinsically salient items (own name), achieved perceptual breakthrough in absence of priming and emotional arousal was predictive of accuracy.

53.4037 **Attentional trade-offs driven by resource scarcity** Brandon Tomm[1](brandon.tomm@psych.ubc.ca), Jiaying Zhao[1,2]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

Operating with limited resources induces an attentional focus on the task at hand, allowing efficient performance, but at the same time such focus may come with a cost. Specifically, scarcity may cause a failure to notice useful information in the environment, even if the information can alleviate the condition of scarcity. This neglect may arise as a result of attentional narrowing, and can explain a range of counter-productive behaviors of the poor (e.g., neglecting benefit programs). We propose that scarcity presents urgent demands that hijack attentional resources, inducing a focus on task-relevant information, but at the same time a neglect of other potentially important information. To directly examine how scarcity tunes attention, we presented participants with a restaurant menu including a list of food items, price information, and calorie information for each item. At the bottom of the menu we included a discount to measure neglect of beneficial information. Participants were randomly assigned to place a meal order with a small budget ($20; poor condition) or a large budget ($100; rich condition). Participants were eye-tracked throughout the experiment. Those in the poor condition prioritized the price information over the food items and the calorie information, compared to those in the rich condition. Critically, poor participants neglected the discount information, even though the discount can alleviate the condition of scarcity. In follow-up memory experiments, participants completed a surprise memory task after their meal order, and we found that the poor participants were more accurate in recalling price information than the rich participants, yet they were no different in calorie recall accuracy. The results suggest that scarcity draws attention to task-relevant information, and selectively facilitates memory encoding. This new account reveals the attentional tradeoffs under scarcity, and can help explain why the poor individuals engage in counterproductive behaviors.

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53.4038 **Attending to multiple ensembles across visual domains imposes no cost relative to multiple ensembles within a single visual domain.** Hayden Schill [1](schhm-16@rhodes.edu), Jason Haberman[1]; [1]Rhodes College

The visual system efficiently perceives the average in a group of similar items. For example, we can accurately derive the average expression of a crowd of faces, the average orientation of a set of lines, and the average size of a group of circles. Although ensembles are created efficiently and with minimal effort, understanding the capacity limitations of ensemble representations remains an active area of research. In the current set of experiments, we explored ensemble capacity limitations by having observers view two sets of ensembles simultaneously. Observers were instructed to attend to both ensembles, presented in a semicircle above and below the horizontal meridian, and then report the mean of the post-cued set. We conducted three experiments, varying the presented ensemble domain in each version: face/gabor, face/color, or color/gabor. Prior to the main experiment, we equated difficulty across ensemble conditions by manipulating variance in a standard QUEST procedure. In each experiment, we contrasted performance in the mixed condition, when multiple ensemble domains were presented concurrently, (e.g., face/gabor), with performance in the unmixed condition (e.g., face/face or gabor/gabor). Interestingly, the results revealed a significant benefit of mixing ensembles in the color/gabor experiment relative to the unmixed conditions. Under no circumstances did mixing ensembles reduce ensemble representation precision, which contrasts with previous work showing a perceptual cost when attending across multiple ensemble domains. However, our finding is consistent with the notion that different ensemble domains are processed independently. We may infer from these results that attending to multiple ensemble domains (mixed condition), in some instances, frees up neural resources relative to attending to multiple ensembles within a single domain (unmixed condition).

Eye Movements: Saccades and perception

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

53.4039 **The effect of stimulus contrast on pre-saccadic orientation discrimination** Mehmet Agaoglu[1](mna@berkeley.edu), Susana Chung[1]; [1]School of Optometry, University of California, Berkeley, Berkeley

Objects that are briefly flashed around the time of saccades are grossly mislocalized. Zhang et al. (2008) demonstrated that these perceptual distortions strongly depend on stimulus contrast such that low-contrast targets are mislocalized more than high-contrast ones. Tong et al. (2012) showed that perceptual grouping by contrast and spatial distortions induced by saccades significantly interact. The purpose of this study was to determine whether similar interactions hold for a discrimination task. Seven observers reported the direction of tilt (clockwise vs. counterclockwise) of a target Gabor patch (2 cpd) presented at 15 deg eccentricity. In two-thirds of the trials, four vertically-oriented Gabors (2 cpd) surrounded the target Gabor. In randomly interleaved blocks, observers performed the task either during steady fixation, or following a saccadic eye movement toward the center of the target Gabor. In the saccade blocks, stimulus timings were adjusted for each observer so that the Gabor stimuli were presented before saccades in the majority of trials. Contrast of the target and flanking Gabors were independent of one another and were either 100% (high-contrast) or 25% (low-contrast) with equal probability. As expected, discrimination performance was worse in the presence of flanking Gabors, for both the fixation and saccade conditions—the crowding effect. In saccade conditions without flankers, significant reductions in discrimination performance as a function of target-to-saccade-onset were observed for low-contrast target Gabors. In the presence of flankers, saccades modulated performance similarly only for low-contrast, but not for high-contrast flankers. Moreover, we did not find any statistical difference between performances in the fixation and saccade conditions. Likewise, the magnitude of crowding was not influenced by saccades, which contradicts a recent report that saccade targets are released from crowding (Harrison et al., 2013). Taken together, our results suggest that pre-saccadic orientation judgments are similarly affected by contrast as perisaccadic spatial localization.

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53.4040 **Saccades and the perceptual organization of surface structure** Nicole Jardine[1](nicole-jardine@uiowa.edu), Cathleen Moore[1]; [1]Psychological & Brain Sciences, University of Iowa

Evidence suggests that saccades and covert attention rely on shared neural architecture. Moreover, there is evidence that covert attentional processing is sensitive to surface-based representations of objects, and that saccades are influenced by the center-of-gravity of objects (Melcher & Kowler, 1999). It is not yet known, however, whether saccades obligatorily reflect surface structure of objects. METHOD: We asked whether saccade distractor-driven curvature is modulated by surface structure. In a saccade-to-target task we manipulated the presence and absence of a distractor, along with surface context, such that the distractor and target could be on the same or on different surfaces. FINDINGS: Three experiments found both early (initial curvature) and late (maximum curvature, landing distance) effects of the distractor on saccades (Van der Stigchel, Meeter, & Theeuwes, 2006), but none of these effects was affected by surface structure. We tentatively conclude that the saccade program does not obligatorily encode the perceptual organization of surfaces. Further experiments are exploring the contrast between these findings and those of Melcher & Kowler (1999).

53.4041 **Saccade preparation reshapes perceptual tuning** Hsin-Hung Li[1](hsin.hung.li@nyu.edu), Antoine Barbot[3], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, New York, [2]Center for Neural Science, New York University, New York, [3]Center for Visual Science, University of Rochester, New York

Purpose. During saccade preparation, visual sensitivity at the saccade target is enhanced. Here, we used reverse correlation to investigate whether and how saccade preparation modulates gain, orientation tuning and spatial frequency tuning at the saccade target. Method. Observers performed a detection task on test stimuli presented at one of two locations (10° left or right from fixation). The target was a vertical grating (0.8° Gaussian envelope; 1.5 cpd) presented in half of the trials, and embedded in random noise. In the saccade blocks, a central pre-cue instructed observers to saccade to the cued location. After a random SOA (12-224 ms) following the cue, the test stimulus (noise or noise+target) flashed briefly at the cued location. In the neutral blocks, a central pre-cue pointed to both locations and observers maintained fixation throughout the trial. Results. We analyzed the data time-locked to the saccade onset. When the target was presented in a critical presaccadic interval (within 50 ms before saccade onset), observers' d´ in the saccade condition significantly improved, compared to the neutral condition. Using reverse correlation analysis, we found that saccade preparation affected sensitivity to orientation and spatial frequency information: i) orientation: enhanced gain and narrowed tuning width. ii) spatial frequency: shift of the tuning peak toward higher spatial frequencies. By analyzing the orientation tuning and spatial-frequency tuning at multiple presaccadic time windows, we found that the reduction of the orientation-tuning width and the shift of the spatial-frequency-tuning peak became more pronounced as time approached saccade onset. Conclusion. Upcoming eye movements altered visual processing: Enhanced visual sensitivity at the saccade target was mediated by enhanced gain, sharpened orientation tuning and a shift of spatial-frequency tuning, which were dynamically modulated during the presaccadic interval.

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53.4042 **Where You Look Matters for Body Perception: Preferred Gaze Location Causally Contributes to the Body Inversion Effect**
Danielle McKean[1,2](dmckean1@uthsc.edu), Joseph Arizpe[1,2], Annie Chan[1,2]; [1]University of Tennessee Health Science Center, Department of Neurology, Memphis, TN, [2]Le Bonheur Children's Hospital, Memphis, TN

Similar to that of faces, visual processing of human bodies involves perceptual mechanisms distinct from those for processing other object categories. For example, the Body Inversion Effect (BIE; reduced visual discrimination performance for whole inverted bodies compared to whole upright bodies) is larger than inversion effects for other object categories, except for faces. This suggests that bodies are processed configurally; however, a robust BIE also exists for bodies without either arms or legs. Further, the importance of specific feature information, namely the head posture information, in the BIE has been indicated in reports of reduction or elimination of the BIE for whole bodies with fixed head position and for headless bodies. Through measurement of gaze patterns and investigation of the causal relation of fixation location to visual body discrimination performance, the present study reveals the joint contributions of body feature and configuration processing to visual body discrimination. Our results reveal that during body discrimination, participants predominantly directed gaze at the upper body for upright bodies and the lower body for inverted bodies. Subsequent manipulation of fixation location indicates that these differential gaze locations contributed to the BIE for whole bodies largely due to the informativeness of gazing at or near the head. Also, a BIE was detected for both whole and headless bodies even when fixation location on the body was held constant, indicating a role of configural processing in body discrimination, though inclusion of the head posture information was still highly discriminative in the context of such processing. Therefore, in addition to the differential gaze patterns, seeing a body in a typical versus an atypical configuration as such (i.e. upright versus inverted orientation per se) also drives the BIE. Interestingly, the impact of configuration (upright and inverted) to the BIE appears greater than that of differential preferred gaze locations.

53.4043 **Temporal dynamics of attention before anti-saccades**
Laura Mikula[1,2](mikula.lora@gmail.com), Marilyn Jacob[1], Laure Pisella[2], Aarlenne Khan[1]; [1]School of Optometry, University of Montreal, Montreal, QC, Canada, [2]ImpAct team, Centre de Recherche en Neurosciences de Lyon (CRNL), Inserm U1028, CNRS UMR 5292, Bron, France

Previous studies have shown that attention shifts to the saccade goal before movement onset (e.g. Deubel et al., 2008), with a peak approximately 50 ms before saccade onset. The current experiment investigated the timing and dynamics of this attention shift during anti-saccade planning; we investigated whether attention shifts only to the anti-saccade goal location (SG) or to the target location (TL) or both, and when. To do so, we asked participants to perform a dual-task paradigm (similar to the one used by Deubel & Schneider, 1996), involving performing blocks of either anti-saccades or pro-saccades as well as discriminating symbols (DS) at the same time. The DS appeared during the saccade latency at the SG location, the TL or a control location (with distractors appearing at all other locations). We calculated discrimination performance at these three different locations as a function of time. For pro-saccades, we replicated previous findings; discrimination performance at the TL/SG location improved the closer the DS onset was to saccade onset (55.6% at -300 ms (±40ms) to 71.1% at -100ms). For anti-saccades, we found that performance was best at the SG location (77.8%), however performance was also higher at the TL (54.7%) compared to control locations (38.7%). In terms of timing, similar to pro-saccades, performance improved the closer the DS onset was to the anti-saccade onset at the SG location (75% at -260 ms to 87.9% at -100ms). For the TL, performance was high when the DS onset was long before saccade onset and decreased close to saccade onset (63.3% at -260 ms to 47.8% at -100ms). These findings suggest that attention can be directed to multiple locations depending on the task but that close to saccade onset, attention is predominately directed to the saccade goal location.

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53.4044 **What do the Eyes Reveal? Visual Attention Strategies During Mental Rotation**
Katherine Moen[1](kmoen1@lsu.edu), Melissa Beck[1]; [1]Louisiana State University

Are the attention strategies associated with better performance on a mental rotation task evident through eye movements? Previous research suggests that experts and novices use different attention strategies during mental rotation tasks. Experts tend to use feature-based strategies by only rotating select parts of objects, whereas novices tend to use more holistic rotation strategies and rotate objects in terms of the whole rather than the parts (Stieff, 2007). Additionally, some research suggests that individuals may only attended to one part of an object, specifically the top, in order to mentally rotate objects (Xu & Franconeri, 2015). The current study sought to further explore strategies during a mental rotation task by tracking eye movements. Participants viewed pairs of three dimensional block configurations and responded if the two stimuli were rotated versions of the same stimulus or two different stimuli. Behavioral results replicated previous research in that accuracy decreased and response time increased as angular disparity increased (Just & Carpenter, 1985; Stieff, 2007). Eye movement data revealed that participants' dwell times were longer on the center of the object space compared to peripheral object space. Additionally, there was a positive correlation between accuracy and dwell time on the center of the object space, suggesting more time spent looking at the center of the object space was associated with increased accuracy. Consistent with previous novice research (Stieff, 2007), participants tended to look at the center of the object space in order to use object-based attention more so than feature-based attention. Additionally, switching between objects more frequently was positively correlated with accuracy. Therefore, successful mental rotation is associated with multiple comparisons.

53.4045 **Malleable pre-saccadic shift of attention**
Michael Puntiroli[1](michael.puntiroli@unige.ch), Dirk Kerzel[1], Sabine Born[1], Heiner Deubel[2], Martin Szinte[2]; [1]Faculté de Psychologie et des Sciences de l'Education, Université de Genève, Genève, Switzerland, [2]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany

When preparing a saccade, attentional resources are deployed towards the saccade target, but do not spread towards surrounding locations. Here we show that such binding of pre-saccadic attention with the saccade target location only holds when eye movements are prepared towards an object still present, but not towards a recently extinguished one. In our study, participants made 10 degree saccades toward an object that could either remain present or get extinguished before the onset of the saccade. We obtained detailed maps of pre-saccadic shifts of attention to the saccade target and its surrounds. We observed that when saccades were prepared towards an object currently present, attention was concentrated within a ~2 degree-radius around the object. However, when saccades were prepared towards an object that extinguished shortly before the saccade (~500 ms), although eye movements remained highly precise, attention was reduced at the saccade target. Interestingly, when saccades were prepared towards an object that disappeared long before the eyes moved (~900 ms), attention spread to locations further away (within a ~5 degree-radius) from the memorized object. Our findings therefore suggest that the pre-saccadic shift of attention is a highly malleable process, bound to he saccade target only when a structured visual field can funnel it.

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53.4046 **Evolutionary-based threat modulates infants' predictive tracking of visual stimuli**
Adi Rosenthal[1](arose34@emory.edu), Vladislav Ayzenberg[2], Samuel Hunley[2], Stella Lourenco[2]; [1]Psychology, Emory College of Arts and Sciences, Emory University, [2]Psychology (Cognition & Development), Laney Graduate School, Emory University

Research with human and non-human primates suggests specialized visual processing of evolutionary-based threats (e.g., Ohman & Mineka, 2001). For instance, human adults and infants underestimate the arrival time of looming animals that are evolutionarily threatening (e.g., snakes

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and spiders) to a greater degree than nonthreatening animals (e.g., rabbits and butterflies) (Ayzenberg, Longo, & Lourenco, 2015; Vagoni, Lourenco, & Longo, 2012). However, it is unclear what accounts for this relationship between threat and visual perception. In the current study, we tested the possibility that human infants misperceive the speed of evolutionarily threatening animals. More specifically, we used a predictive tracking paradigm to determine whether the perceived speed of laterally moving images differed depending on the threat value. Twenty-six infants (8- to 11-month-olds) were presented with horizontally moving images of threatening (i.e., snakes, spiders) and non-threatening (i.e., rabbits, butterflies) animals at two velocities (50 mm/s and 100 mm/s). A portion of the movement trajectory was covered in the center by an occluder, thereby forcing infants to anticipate the image' reappearance. As in previous studies (Von Hofsten et al., 2007) infants predictively tracked the images through the occluder ($p < .05$) and the speed of anticipatory looks to the exit-side of the occluder scaled according to velocity ($p < .05$). Finally, and critically, preliminary results reveal that, among slow trials, infants' anticipatory looks were earlier for threatening than nonthreatening stimuli ($p = .078$, $\eta 2 = .205$). These data suggest that infants' perception of speed may be modulated by the threat value of the animal, providing evidence for specialized spatiotemporal perceptual processing of evolutionary-based threat.

53.4047 **Feature prediction across eye movements is location specific** Arvid Herwig[1,2](aherwig@uni-bielefeld.de), Katharina Weiß[1,2], Werner Schneider[1,2]; [1]Department of Psychology, Bielefeld University, Bielefeld, Germany, [2]Cluster of Excellence, "Cognitive Interaction Technology," Bielefeld University, Bielefeld, Germany

With each saccade, internal object representations change their retinal position and spatial resolution. The same object will be represented with high acuity in the fovea but only coarsely in periphery. Recently, we suggested that the visual system deals with these saccade induced changes by predicting visual features across saccades (Herwig & Schneider, 2014, JEP:G). Such predictions are assumed to be based on transsaccadic associations of peripheral and foveal input causing peripheral perception to be biased toward previously associated foveal input. Up to now, effects of transsaccadic feature prediction on peripheral perception have been exclusively reported for saccade targets presented at previous learning locations. In the present study, we tested whether feature prediction is bound to the saccade target location and/or the previous learning location. Replicating the study of Herwig and Schneider (2014) participants first underwent an acquisition phase, where, unnoticed by most participants, one out of two objects systematically changed its spatial frequency during saccades. In the following modified test phase, participants had to judge the frequency of briefly presented peripheral target objects (PTO). Saccades were either directed at a PTO or at another neutral object presented at the same eccentricity. Moreover, PTOs could be presented either at the previous learning location or at obliquely displaced locations. Following acquisition, spatial frequency of PTOs was perceived as lower (higher) if they previously changed from high (low) in the periphery to low (high) in the fovea indicating transsaccadic feature prediction. Importantly, this pattern was seen only at the previous learning location independent of the PTO being the saccade target object or not. These results indicate that peripheral perception of spatial frequency is specifically biased toward previously associated postsaccadic foveal input. They further suggest that feature prediction is bound to the previous learning location but not to the saccade target location.

53.4048 **Tracking choices before they are made: Saccadic decisions bias perceptual selection** Anna Klapetek[1](anna.klapetek@psy.lmu.de), Donatas Jonikaitis[1,2]; [1]Allgemeine und Experimentelle Psychologie, Ludwig-Maximilians-Universität München, [2]Department of Neurobiology and Howard Hughes Medical Institute, Stanford University School of Medicine

There is ample evidence that saccadic decisions are represented in the oculomotor system, but our understanding of the underlying mechanisms is limited, as we can normally only observe the consequences of the decisions in the form of eye movements. In the present study we investigated whether decision making can be traced before a particular response is selected and executed, and measured this in free choice and rule-based choice situations. For this purpose we took advantage of the fact that the oculomotor system facilitates perceptual selection at the goals of planned saccades. Participants were asked to memorize two spatial locations, highlighted by different colors. After a delay period, the color of the central fixation changed and either indicated one of the memorized locations as the saccade target (rule-based choice), or indicated to freely choose between the two locations. By probing discrimination performance at variable SOAs relative to this cue, we were able to measure the time course of the perceptual selection of both targets. In both rule-based and free choice trials, we observed a parallel perceptual selection of the chosen saccade target and the non-chosen target. Despite the fact that both targets were selected, there was a clear bias towards the saccade target. This bias was evident before correct as well as before erroneous rule-based responses. In conclusion, our results demonstrate that motor decisions have direct sensory consequences. This offers a new way of how decision making in the human oculomotor system can be traced.

Visual Memory: Capacity and resolution

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

53.4049 **Competitive interactions occur during working memory encoding and iconic memory but not during working memory maintenance.** Jumana Ahmad[1,2](jumana.ahmad@kcl.ac.uk), Garrett Swan[3], Howard Bowman[1,5], Brad Wyble[3], Anna Nobre[4], Kimron Shapiro[1], Fiona McNab[1]; [1]School of Psychology, University of Birmingham, Birmingham, UK, [2]Department of Forensic and Neurodevelopmental Science, Kings College London, London, UK, [3]Department of Psychology, The Pennsylvania State University, Pennsylvania, USA, [4]Department of Experimental Psychology and Oxford Centre for Human Brain Activity, University of Oxford, Oxford, UK, [5]School of Computing, University of Kent, Canterbury, UK.

Competition has typically been manipulated by simultaneously presenting two visual items within the same receptive field (RF). Such competition originates at perception, and is associated with longer reaction times, reduced BOLD response and reduced neural firing. Previously we observed that perceptual competition affects working memory (WM) performance. In that study we manipulated competition during WM encoding by varying the spatial proximity between two simultaneously presented items (Near vs. Far conditions). Participants were required to report the colour of a target item on a colour wheel. Relative to the Far condition, the Near condition was associated with reduced WM precision and an increase in the number of times the colour of the un-cued item was erroneously reported. Here four experiments are presented, where competition was manipulated between items in iconic or working memory, but not during perception. Two items were presented sequentially, and the second item appeared either in close or distant spatial proximity to the first item (Near vs. Far conditions). The temporal interval between the first (S1) and second (S2) item was either 0ms (Experiment 1), 500ms (Experiment 2), or 1000ms (Experiment 3). In Experiment 1, relative to the Far condition, the Near condition was associated with reduced precision and more reports of the colour of the un-cued item. However, in Experiments 2 and 3 these effects were absent. In Experiment 4 we encouraged participants to maintain the two items in either the precise spatial locations in which they were presented by adding a location judgment task to 25% of trials. Despite this manipulation, there was no evidence of competition. We conclude that WM performance is vulnerable to competition when items compete during WM encoding or within iconic memory, but not when the competition can only occur within WM.

53.4050 **Working memory capacity predicts the efficiency of transfer into long-term memory** Kirsten Adam[1](kadam1@uchicago.edu), Edward Vogel[1]; [1]University of Chicago

Visual Working Memory (WM) capacity is limited to around 3-4 simple items, yet the capacity of long-term memory is virtually unlimited. Here, we measured increases in WM performance across back-to-back repetitions of identical supra-capacity arrays. We hypothesized that subjects would show typical capacity limits for the first presentation of an array but reach near-perfect performance when they are able to recruit long-term memory resources after multiple repetitions of the same array. Further, if WM acts as a gateway for the transfer of information into long-term memory, then WM capacity should predict the change in performance across repetitions. On each trial, subjects (N = 31) saw an array of 6 colored squares, remembered the array across a blank delay, and then reported the identity of all items in the array. The same array was repeated for 8 trials. Participants completed a total of 240 trials (30 unique arrays), and performance was calculated as the number of correctly reported items for each trial. After the repetition task, participants performed a surprise old-new recognition task and a change detection measure of visual working memory capacity. As predicted, WM performance showed typical limits for the first presentation of the array (~2.75 items correct) and surpassed typical limits after several presentations (>5 items correct). A separate measure of capacity predicted both the rate of performance increase across repetitions ($r = .54$) and performance on

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the surprise long-term memory test (r = .58). Thus, we find support for the notion that working memory capacity influences the number of encounters needed to successfully encode a large array of items into long-term memory.

53.4051 Inter-item distortions in visual working memory Christoph Bledowski[1](bledowski@em.uni-frankfurt.de), Benjamin Rahm[2], Victoria Anschütz[1], Benjamin Peters[1], Jochen Kaiser[1], Stefan Czoschke[1]; [1]Institute of Medical Psychology, Goethe University Frankfurt, [2]Medical Psychology and Sociology, Johannes Gutenberg University Mainz

Current models of working memory (WM) assume that mnemonic representations of individual items are stored independently of one another. Recent studies, however, have indicated that WM representations interact, leading to systematic distortions along their feature dimension. In a series of experiments we found that several aspects of the encoding situation influence whether this interaction leads to attraction or repulsion between two retained dot motion directions. Items consistently repulsed each other when presented simultaneously during encoding. When presented sequentially, however, inter-item interactions depended strongly on an item's serial position within and between trials as well as on the spatial and temporal characteristics of the item presentation. First, similar to the serial dependence effect of perception we found that an item memorized on the preceding trial attracted its successor in the current trial. In contrast, when both items belonged to the same trial, the preceding item (S1) repulsed the successor (S2). Next, we investigated in more detail the distortion effect on S1 and S2, separately, by manipulating the their spatial position and inter-stimulus interval (ISI). Interestingly, we found opposing distortion patterns for the S1 and S2. Specifically, when items were presented at different instead of the same retinal position: S2 attracted S1, whereas no systematic bias in responses to S2 was observed. However, when both items were presented in immediate succession instead of being separated by different ISIs, S2 was again repulsed by S1, despite different positions. Our results provide new evidence for systematic inter-item distortions in WM. Interestingly, the observed distortions varied considerably between different encoding conditions and serial positions within and between trials, hinting at different origins of the distortion effects. These findings may demand an extension of the current WM models.

53.4052 Objects held in visual working memory compete for access to resources. Oakyoon Cha[1](oakyoon@yonsei.ac.kr), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

The current study tested the manipulation aspect of encoded items in VWM by indicating possible target items using multiple cues (i.e., retro-cues) after encoding. We hypothesized that the retro-cues would cause the cued items to compete for resources in order for successful maintenances of those items. Specifically, we expected that this competition would decrease the precision of memory representation. In Experiment 1, three arrows were presented as to-be-encoded items, and then a ring-shaped retro-cue(s) indicating one or two encoded location(s) were shown in a retention period. The same-shaped report cue was shown in one of the three locations of the encoded items and prompted participant to recall the orientation of the arrow in the cued location. Results showed that the precision of the reported orientation was lower when two items were cued than when one item was cued, suggesting that there was a competition among the items encoded in VWM. Experiment 2 manipulated the degree of competition by varying the encoding strength of memory items. Specifically, the appearance of two memory items (early-onset items) was followed by that of one item (late-onset item), with all the items simultaneously disappearing later. After the encoding, two items (two early-onset items or early- and late-onset items) were always cued with the equal probability. The same report cue was used to prompt participant to recall the orientation of the arrow. We found that the precision of the reported orientation was lower when the two early-onset items were cued than when the early- and late-onset items were cued, suggesting that the precision of memory representation differs depending on the memory strength of competitors. Taken together, our results suggest that items in VWM compete against each other for access to resources, which was reflected in the precision of memory representation.

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53.4053 Probabilistic Information in Visual Working Memory Maija Honig[1](maija.honig@nyu.edu), Daryl Fougnie[2], Wei Ji Ma[1]; [1]New York University Center for Neural Science and Department of Psychology, [2]New York University Abu Dhabi Department of Psychology

Current theories assume that a stimulus is stored in working memory as a point estimate, e.g. a specific color value. Another possibility is that memory representations are richer, perhaps containing a probability distribution on every trial. To test for this possibility, we conducted a delayed-estimation experiment in which subjects reported both a stimulus estimate and an uncertainty value. They remembered the colors of four items, after a delay estimated the color of a randomly chosen item on a continuous color wheel, and finally adjusted the size of an arc over that wheel centered on the estimate. When the true color was "captured" by the arc, the subject received points; the points decreased linearly with increasing arc size. This incentivized subjects to report an arc size that reflected their memory uncertainty on that trial. To examine in more detail how people utilized memory uncertainty, we introduced prior beliefs about likely colors by training subjects on one of two color distributions: either uniform (all colors are equally likely) or Von Mises (some colors are more frequent than others). We found that when subjects reported a larger arc size (higher uncertainty), their error was higher, suggesting that they possessed meta-knowledge of memory quality. Moreover, when colors came from a Von Mises distribution, reports were biased towards the most frequent color and the amount of bias increased with increasing arc size. These patterns of results are consistent with a Bayesian-observer model in which memory uncertainty is represented, varies across trials, and gets combined with prior beliefs and reward information to produce a response. These results support that probabilistic information is stored in visual working memory, and that people have access to this information and incorporate it into decisions.

53.4054 Focusing on memory: Attentional focusing increases the effective capacity of visual working memory Lisa Jefferies[1](L.Jefferies@griffith.edu.au); [1]School of Applied Psychology, Griffith University, Gold Coast, QLD

Visual working memory (VWM) is essential for a vast range of cognitive processes, and an individual's VWM capacity strongly predicts both their fluid intelligence and their actual performance on a variety of tasks. VWM is limited in capacity, however, which translates into measurable constraints on cognition and performance. There are hints in the literature to suggest a close association between attention and VWM, and the present study tested whether attentional focusing – expanding or contracting the spatial extent of the attentional focus – modulates the number of items that can be held in VWM. In Experiment 1, large or small spatial precues were presented abruptly at the beginning of each trial, triggering reflexive attentional focusing. A change-detection task in which 4, 6, or 8 colored squares were presented briefly at random locations in the centre of the display was used to estimate VWM capacity (K). The results showed that reflexively narrowing the focus of attention significantly increases the effective capacity of VWM. Experiment 2 assessed whether endogenous focusing would also affect VWM. To this end, large and small precues were spatially superimposed and presented continuously throughout each block. Participants were instructed to attend either to the large or the small precue. To ensure the instructions were followed, the memory array items were presented around the edges of the relevant cue on 75% of the trials. On the remaining 25% of the trials (the critical trials), the memory items were presented in the centre of the display. As in Experiment 1, K was significantly larger when attention was narrowly focused. In both experiments, the benefits of focusing were most evident when the VWM task was difficult. The present findings show that changing how an individual deploys attention significantly increases the effective capacity of VWM. Implications for models of VWM are considered.

53.4055 Memory capacity is further limited when sensory modality and task are mismatched James Lynch[2,3](jdlynch@bu.edu), Abigail Noyce[1], Barbara Shinn-Cunningham[1], David Somers[4]; [1]Department of Psychological and Brain Sciences, Boston University, [2]Undergraduate Program of Neuroscience, Boston University, [3]Undergraduate Program of Psychology, Boston University, [4]Comp-Net, Boston University

Spatial locations are perceived and represented more accurately by vision than by audition, while time intervals are perceived more accurately by audition (Welch & Warren 1980). These task-modality relationships also occur in working memory tasks (e.g. Guttman 2005, Lehnert & Zimmer 2008). Here, we test whether differences between vision and audition when remembering locations and intervals arise from corresponding differences in working memory capacity. We hypothesized that, particularly at low memory loads, capacity estimates and sensory modality would interact, with capacity increasing more quickly in the task-appropriate modality (i.e., vision for spatial tasks) as memory load increased. To test this, participants (n=10) performed eight change detection tasks with memory loads of two or four items (varying sequence length). Participants compared two short sequences presented either visually or auditorily, and looked for changes in either the order of spatial locations (left/right), or the order of inter-item intervals (short/long). Visual stimuli comprised an array of two static images (photographs of animals on a white background); visual sequence elements were an instantaneous mirror flip of one image. Auditory stimuli comprised a stream of complex tones, each of which was one auditory sequence element. Visual stimuli had spatial positions on a computer monitor; auditory stimuli were lateralized by interaural time differences of ±1 ms. Inter-item intervals were 300 and 720 ms. As hypothesized, larger memory loads led to increased capacity estimates on both spatial and temporal change detection tasks, with greater increases for the task-appropriate modality. Capacity estimates in task-inappropriate modalities remained near or below one item. This interaction between task domains and information modality supports an account of separate working memory stores for spatial locations and for time intervals, with privileged access for visual and auditory modalities, respectively.

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53.4056 Alpha band fluctuations in iconic memory recall Stephanie Nelli[1,2](smnelli27@gmail.com), Rachel Chen[2], John Serences[1,2]; [1]Neurosciences Graduate Program UCSD, [2]UCSD Department of Psychology

Iconic memory is a quickly decaying, fragile memory trace with a larger capacity than standard working memory (Sperling 1961). This transient visual memory buffer plays a key role in temporal integration (Nikolic et al 2009) and change detection (Urakawak et al 2010) and more generally in the consolidation of information into more durable forms. In addition, several recent studies have identified alpha-band (8-12 Hz) rhythmicity in behavioral performance when subjects are asked to detect a near-threshold visual stimulus (Fiebelkorn et al 2013, Laundau & Fries 2013). Here we asked if these rhythmic modulations in detection performance are due primarily to failures in initial sensory encoding or failures in iconic memory storage (and further consolidation). On each trial, we used a white full-field flash to reset the phase of alpha oscillations. We then briefly (25 ms) presented a circular target array of 8 letters at pseudo-randomly chosen timepoints ranging from 225 to 1400 ms after the reset flash. Finally, subjects were asked to report the 3 letters indicated by a post-cue occuring at delays of either 100, 400 or 1000 ms after target array presentation. Subjects recalled a significantly higher proportion of letters at short vs. long target-to-cue delays, replicating previous results in the iconic memory literature (Sperling, 1961). Furthermore, observed 10-14 Hz oscillations in behavioral performance were most prominent at the shortest target-to-cue delay interval. This is consistent with an influence of intrinsic alpha oscillations on information stored in high-capacity, but fragile, iconic memory.

53.4057 Rapid Access to Visual and Semantic Representations in Iconic Memory Jasmina Vrankovic[1,2](jasmina.vrankovic@mq.edu.au), Veronika Coltheart[1], Nicholas Badcock[1,3]; [1]ARC Centre of Excellence in Cognition and its Disorders, Macquarie University, [2]Department of Psychology, Macquarie University, [3]Department of Cognitive Science, Macquarie University

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We can easily understand the visual environment despite our eyes moving to take in new information three to four times per second. This rapid information flow may initially be registered in iconic memory, a brief high-capacity store containing literal visual representations. Evidence for higher-level semantic representations in iconic memory has not been demonstrated and it has been proposed that such representations may only be accessed in subsequent stages of memory, for example, visual short-term memory and phonological short-term memory stores. Two experiments aimed to investigate whether visual and higher-level semantic representations can be accessed in the very early stages of visual memory by using comparable iconic memory tasks. A novel partial-report paradigm was used where participants were briefly shown arrays of six pictures at various exposure durations (50 ms, 150 ms, and 250 ms). Following array offset, a cue specified full report (recall of all six pictures) or partial report (recall of only one cued picture). Experiment 1 investigated whether location information (a pointer to a spatial location) could cue recall. Experiment 2 investigated whether semantic information (instruction to report a picture belonging to a particular semantic category) could cue recall. In both experiments, performance was superior in the partial-report condition compared with the full-report condition (partial-report superiority). These results suggest that several pictures from each array must rapidly gain access to a store in which visual representations are attached to spatial locations and access higher-level semantic information. In both experiments, recall was unaffected by an increase in exposure duration from 50 ms to 150 ms but it improved significantly with the longer 250 ms exposure duration. The evidence for both early visual and higher-level semantic processing in iconic memory tasks challenges the initial conceptualisation of iconic memory and its role in subsequent stages of memory.

53.4058 Visual working memory capacity for orientation depends on stimulus form Young Eun Park[1,2](youngeun.park@vanderbilt.edu), Alejandra Patino[3], Frank Tong[1,2]; [1]Psychology Department, Vanderbilt University, [2]Vanderbilt Vision Research Center, [3]Center for Neural Science, New York University

Much research has centered on understanding the nature of capacity limits in visual working memory. A largely overlooked possibility is that the nature of the stimulus itself might grossly affect estimates of capacity. Here, we investigated whether the precision or capacity of visual working memory for orientation depends critically on stimulus form, encouraged by earlier reports of better change detection performance for bars than for Gabor gratings (Alvarez & Cavanagh, 2008). Participants viewed a circular array of 2 or 6 items of either stimulus type, randomly placed at an eccentricity of 4˚. After a short delay, they reported the orientation of a randomly probed item. A mixture-model analysis (Zhang & Luck, 2008) revealed that memory precision was very comparable for the two stimulus types, but that estimated capacity was about twice as large for bars (5.5 items) as for Gabors (2.6 items). Similar results were obtained when stimuli were presented for 200ms or 1000ms and followed by a patterned mask, ruling out the possibility that gross differences in capacity might be driven by faster encoding or more persistent iconic traces for the bars. Finally, we evaluated the hypothesis that working memory capacity may be superior for bars because their random arrangements can be more readily organized into perceptual groups. To disrupt perceptual grouping processes, we sequentially presented six bars or Gabors at various locations. With sequential presentation, memory capacity for bars dropped from 5.5 to 3.5 items, whereas the capacity for Gabors remained unchanged. These results suggest that higher-order patterns formed by simultaneously presented bars can be more efficiently maintained in working memory. Our findings demonstrate that working memory for orientation is highly dependent on stimulus form. Moreover, any formulations of visual working memory capacity should explicitly consider perceptual factors that allow for more efficient usage of its limited capacity.

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53.4059 The origin of the visual working memory capacity limitations Marjan Persuh[1](mpersuh@bmcc.cuny.edu), Emmanuel Delgado[1], Aharon Zarzar[1]; [1]Social Sciences, Human Services & Criminal Justice, Borough of Manhattan Community College, City University of New York

Visual working memory has very strict capacity limitations; on average, people are able to hold in their memory only between 3 to 4 independent objects. Although most studies examined the maintenance of visual information over time, capacity limitations might originate at the earlier, encoding phase. In the current study, we tested this hypothesis directly; we modified the classical change detection paradigm by eliminating the maintenance phase. In change detection, two stimulus arrays are presented sequentially, with a temporal gap and observers are asked to report a change between two arrays. We have eliminated the temporal gap and presented two arrays simultaneously, side by side, creating a parallel change detection. In the first experiment, we compared detection of change in object orientation in both classical and parallel change detection paradigms. Observers' performance dropped dramatically with increasing set size, even in parallel change detection task, in which two arrays were presented simultaneously. In the second experiment, we tested two visual features, orientation and size and their conjunction in parallel change detection task. We replicated results from the first experiment; furthermore, observers showed similar drop in performance with increasing set size for both, object size and conjunction of size and orientation. Our results suggest that visual working memory capacity limitations originate at the early, encoding phase of visual information processing and are therefore limitations of visual perception and not limitations of memory per se.

53.4060 Evidence for the modulation of visual working memory during exercise. Lindsey Purpura[1](lindsey.purpura@psych.ucsb.edu), Tom Bullock[1], Barry Giesbrecht[1]; [1]Psychological and Brain Sciences, University of California, Santa Barbara

Changes in behavioral state induced by locomotor activity dramatically impact behavioral performance and brain activity. This has been demonstrated in various species from invertebrates to nonhuman primates (Chi-

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appe et al., 2010; Neill & Stryker, 2010). While there is similar evidence from humans (Bullock et al., 2015), the neural mechanisms mediating of the effect of physical activity on cognitive performance are less clear. Here, we investigated whether physical activity modulates visual working memory. Participants (n=6) completed a continuous response visual working memory task (e.g., Zhang & Luck, 2008; Wilken & Ma, 2004) while seated on a stationary bike in three activity conditions: rest (mean heart rate (HR)=74.4 bpm), low intensity cycling (mean HR=106.6 bpm), and high intensity cycling (mean HR=133.7 bpm). Participants viewed a brief display (100 ms) of colored squares; 900 ms after the display offset, one stimulus location was probed and participants indicated the color of the square presented at that location using a selector on a color wheel. An analysis of the absolute response error revealed that errors in the low intensity exercise condition (M(SEM) = 54.18° (3.61°)) were larger than those observed at rest (49.13° (4.74°); t(5) = 3.29, p = .021). Consistent with this analysis, a maximum likelihood estimate of a standard mixture model suggested that the increase in response error is due to a reduced probability in memory and increased resolution of encoded items for supra-capacity arrays during low intensity exercise (probability in memory (Pmem) = 0.22) compared to rest (Pmem = 0.34) and high intensity exercise (Pmem = 0.31). These results are consistent with the conclusion that exercise modulates visual working memory by reducing the likelihood that stimulus information is encoded thus presenting greater error in reported colors during exercise.

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53.4061 Visual Working Memory Has Greater Tolerance Than Visual Long-Term Memory

Mark Schurgin[1](maschurgin@jhu.edu), Jonathan Flombaum[1]; [1]Johns Hopkins University

We propose that visual working memory (VWM) is designed to support the acquisition of appropriately constrained representations in visual long-term memory (VLTM). This novel hypothesis has implications for understanding apparent limitations in VWM, and the mechanisms that transition VWM to VLTM. The prediction is that VWM should have greater tolerance than VLTM; it should more readily recognize objects as the same despite inputs that differ considerably in appearance. We tested this prediction and further investigated the relationship between these systems in several experiments. In the experiments participants were exposed to two (or more) real-world objects in a trial. After a short delay, one of the objects was paired with a new object and the task was to indicate which was in the recently seen set. After 180 trials a long-term memory test probed the previously untested objects against foils in exactly the same way. We observed two especially notable results: In several experiments we injected the test images with varying amounts of noise by randomly scrambling pixels. VWM performance was unaffected, even by 75% noise. But VLTM performance suffered linearly as noise increased. In other experiments, VWM was unaffected when test objects were viewed at a new orientation (compared to exposure), but VLTM performance dropped significantly. Altogether, VWM was more tolerant: willing to recognize an object as the same despite inputs that differed considerably in appearance. These results suggest that what many interpret as noise in VWM may actually be a feature of tolerance. Several experiments manipulating load further support this perspective. The experiments also suggest a new perspective on VLTM, which is often thought of as highly tolerant, designed to accommodate recognition despite changes in viewing conditions. But compared to VWM it is relatively intolerant, suggesting that representations actually become more discriminating as they consolidate in VLTM.

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53.4062 How many trials contribute to statistical representation over time?

Ke Tong[1](ketong@mail.usf.edu), Chad Dubé[1], Robert Sekuler[2]; [1]University of South Florida, [2]Brandeis University

In an effort to model perceptual averaging over time, we investigated a critical element in the process: the number of trials that subjects use when generating a temporal average. In Experiment 1, participants were presented with a sequence of vertical lines. After every line's presentation, they were asked to provide an estimate of the average length of all the lines they have seen to that point. One key manipulation was a sudden shift in the mean line length between the first and the second halves of the sequence. If the participants could use all the previous stimuli in their estimates of the moving averages, their estimates would not increase or decrease immediately after the mean shift. However, results suggested the opposite pattern: the participants' estimates of the moving averages followed closely to the shift of mean values, suggesting, contrary to previous reports (e.g., Morgan, Watamaniuk, & McKee, 2000) that they did not make full use of the previous stimuli. We fit the data with an autoregressive model with variable weights assigned to previous stimuli. Best fitting parameters suggested that only the most recent six trials actually contribute to subjects' estimation of the mean. In Experiments 2 and 3, we ran the same task with other visual stimuli, both perceptual (discs varying in diameters) and symbolic (numerical values). The number of "contributors" was similar to that of Experiment 1, suggesting that the result is robust across different stimulus types. These results suggest that temporal averaging is fundamentally limited by the capacity of working memory. Implications for existing models of visual short-term memory are discussed.

53.4063 A stimulus biased contralateral bias in intraparietal sulcus.

Kyle Killebrew[1](kylekillabees@gmail.com), Ryan Mruczek[1,2], Marian Berryhill[1]; [1]University of Nevada, Reno, NV 89557, [2]Worcester State University, Worcester, MA 01602

The role of the intraparietal sulcus (IPS) in working memory (WM) remains a topic of considerable debate and divergent findings within the literature have made this an even more complex problem. Functional magnetic resonance imaging (fMRI) studies using foveally presented object arrays report bilateral IPS activity corresponding to the number of items held within working memory. Conversely, the electroencephalography (EEG) literature, measuring the slow wave component of the EEG signal often referred to as the contralateral delay activity, report greater activity for stimuli presented contralaterally compared to those presented ipsilaterally. Recent work has tried to rectify these findings by applying more stringent constraints on the hemifield of stimulus presentation. For example, presenting stimuli in both hemifields allows for the differentiation of WM-related activity from that of perceptual activity. Here, we attempt to resolve this discrepancy using a similar approach. Using fMRI and a region-of-interest analysis, we manipulated stimulus type (verbal, visuospatial) and cued hemifield in order to understand the contributions of each region of the IPS to WM. Our data show a significant contralateral bias across all IPS ROIs regardless of stimulus type. There is also a weaker stimulus driven bias in the left hemisphere for verbal stimuli and in the right hemisphere for visuospatial stimuli regardless of hemifield. Overall, these results are consistent with the EEG literature, and a contralateral bias in IPS regions. The results also support theoretical perspectives linking the IPS with a material general role in maintaining information in WM.

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53.4064 How Should Observers Allocate Limited Transsaccadic Memory in a Visual Search Task?

Nicholas Kleene[1](nkleene88@gmail.com), Melchi Michel[1]; [1]Psychology Department, Rutgers University - New Brunswick

Our primary means of gathering information about the world is through eye-movements. Each intervening fixation provides a sample of the visual world. Due to limited visual acuity in the periphery, integrating visual samples across fixations is a critical part of visual perception, and in particular visual search. Transsaccadic memory (TSM) is necessary to store samples from previous fixations to be integrated with the current one. Therefore, we sought to place a lower bound on transsaccadic memory capacity using two visual search experiments: a real saccade experiment and a simulated saccade experiment. The task in both was to localize a target signal (Gabor) embedded within a field of 1/f filtered noise. Participants were presented with one, two or four intervals of the stimulus, with the target either present in every interval (redundancy condition) or just one (uncertainty condition). In the real saccade experiment, participants were required to make a 5° eye-movement following each sample of the stimulus; in the simulated saccade task observer's maintained fixation while we simulated the dynamic transient caused by saccades. Performance was measured as target localization accuracy. Using an ideal observer model fit to each participant's sensitivity we found higher TSM capacity estimates in the real saccade experiment compared to the simulated saccade experiment. Previously, we assumed a simple encoding strategy wherein TSM capacity was divided evenly among the individual fixation intervals and target locations (Kleene & Michel, 2015). Removing this assumption, we found that a strategy that allocates TSM according to the posterior probability at each potential target location significantly improved performance for simulated observers with small TSM capacity relative to task demands. Additionally, simulated observers with smaller TSM capacity required greater weighting of previous information to achieve optimal performance. Therefore, as task demands on TSM increase, dynamic allocation of TSM capacity becomes more beneficial.

Acknowledgement: NSF BCS1456822

53.4065 **A Comparison of Haptic and Visual Memory Suggests Domain General Principles in Perceptual Working Memory** Rachel Lerch[1](Ral93@drexel.edu), Chris Sims[1]; [1]Department of Psychology, Drexel University

There exists a long history of capacity limitations cited in the visual working memory (VWM) literature. It is less clear however, whether the types of limitations commonly observed reflect unique properties of the visual system per se or rather a more general property of perceptual stimuli encoded in working memory. In other words, should the study of VWM be replaced by the more encompassing concept of perceptual working memory? We make a qualitative comparison of memory performance between two perceptual modalities: haptic working memory (HWM) for object width, and VWM for line length. In the haptic memory experiment, participants were presented with a sequence of 1–4 object widths (experienced with the thumb and pointer finger) and made a 'wider or narrower' judgment against a probe item. We compared performance in the haptic memory experiment with previous data examining visual working memory for line length (Sims et al., 2012). The analyses from both studies were approached using rate–distortion theory, a branch of information theory. The results yielded several qualitatively similar findings. First, HWM performance like VWM performance showed a set size effect. This decline was notably more substantial in HWM performance than that of VWM, particularly when more than one item was held in memory. Additionally, discrimination for haptic width degraded in a manner similar to visual line length discrimination as set size increased. Lastly, both analyses revealed biases to the mean of the stimuli distribution and the magnitude of this bias increased as set size increased. This finding suggests that implicit statistical learning plays a central role in both visual and haptic working memory. The relatedness of the findings between the two sensory modalities suggests that characteristics of performance commonly observed in VWM may be better understood as characteristics embodied by a larger perceptual working memory system.

53.4066 **Quantifying the effect of a distractor on the fidelity of visual working memory representations in 4-7-year-old children and adults** Sylvia Guillory[1](Sylvia.Guillory001@umb.edu), Zsuzsa Kaldy[1]; [1]Department of Psychology, University of Massachusetts Boston

Introduction: Selective attention plays a pivotal role in what information enters our working memory. Following the design of Huang & Sekuler (2010), we investigated how task-irrelevant information (a distractor item presented during memory maintenance) can impact the fidelity of visual working memory (VWM) representations in 4-7-year-old children compared to adults. Methods: Using a delayed estimation task with line orientation stimuli, participants (N = 30 adults, N = 15 children) completed three blocks of trials: perceptual matching (baseline), a 1-item VWM task, and a serially presented 2-item VWM task. A response dial was used to manipulate the probe's line orientation to match the target's. In the 2-item task, participants were cued at the beginning of the trial to remember the first item in the series. Results and Discussion: In the 2-item task, results of 4-7-year-olds demonstrated a greater shift toward the distractor (M = 0.15 degrees of error, SD = 0.087) in comparison to adults (M = 0.036 degrees of error, SD = 0.061), $F(1,43) = 26.57$, $p < 0.001$. In addition, the precision of recall (in the 1-item task) significantly improved with age where precision is calculated as 1/SD, $F(1,43) = 89.56$, $p < 0.001$ (adults: M = 6.39 rad-1, SD = 1.48, children: M = 2.57 rad-1, SD = 0.66). To our knowledge, this is the first investigation of the effects of distractors on the fidelity of memory representations in children. We found that young children's memory representations are more susceptible to the influence of a distractor and this is likely due to immature attentional control systems.

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Visual Memory: Objects and features

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

53.4067 **The sum is no more than its parts: No evidence for bound features during multi-feature visual change detection** Alex Burmester[1](alexburm@gmail.com), Daryl Fougnie[1]; [1]Department of Psychology, New York University Abu Dhabi (NYUAD)

Studies have shown that we can hold very little information in working memory, even for simple visual features. But what type of information is stored in working memory? Some have suggested that we store coherent bound objects (e.g. colored triangles; Luck & Vogel, 1997). Others have suggested that the units of memory are individual visual features (e.g. color or orientation features; Bays, Wu, & Hussain, 2011; Fougnie & Alvarez, 2011). Reconciling the different findings in the literature is challenging due to the fact that studies used different tasks. Studies that have supported the 'features-bound' hypothesis have typically used change detection accuracy judgements. In contrast, studies that support the 'features-unbound' hypothesis have used production tasks where participants adjust feature values to match memory items. A concern is that different tasks may affect working memory representations. To explore this we contrasted feature-bound and feature-unbound accounts using a change detection task in which the number of changing features (one or two) was manipulated between and within objects. Both accounts predict improved performance with two changes. The features-unbound hypothesis predicts equivalent performance for two changes within and between objects. Critically, the features-bound hypothesis predicts that performance for one feature changing in two objects will be better than two features of one object changing, since the latter only allows improvements if participants miss a feature change and not if they didn't store that object. We found evidence consistent with unbound features (N=12). Change detection performance was equivalent for two objects changing a single feature (color in one object, orientation in the other) and for one object changing two features (colour and orientation). Furthermore, the data was well explained by a model where features were remembered independently across objects. We suggest that features, not coherent objects, are the units retained in memory.

53.4068 **Feature binding in visual working memory is disrupted by task-irrelevant changes in object features.** Andrea Bocincova[1,2](andrea.bocincova@ndsu.edu), Amanda van Lamsweerde[1,2], Jeffrey Johnson[1,2]; [1]Department of Psychology, North Dakota State University, [2]Center for Visual and Cognitive Neuroscience, North Dakota State University

Feature binding refers to the process by which the individual features of a stimulus are combined into an object representation. Previous research suggests that features may be initially bound via their shared location, although location becomes less crucial once visual working memory (VWM) representations are established. Task-irrelevant location changes become less disruptive to color-shape binding memory as the retention interval increases, suggesting that object information is abstracted from location over time (Treisman & Zhang, 2006). To determine whether task-irrelevant changes in color or shape can also be ignored at longer delays, Logie et al. (2011) examined the effect of randomizing of task-irrelevant features at test across different study-test intervals. When remembering color-shape, color-location or shape-location bindings, randomizing along the task-irrelevant dimension was detrimental at shorter (~0-1000 ms), but not at longer study-test intervals (>1000 ms). They concluded that all features were rapidly integrated into objects during perception; however, once in VWM, top-down control mechanisms can be used to suppress the task-irrelevant feature representation, eliminating the detrimental randomization effect at longer intervals. To test the role of top-down control processes in the inhibition of task-irrelevant features during VWM maintenance, we replicated this color-location binding task, but included a concurrent attention load on half the trials (counting backward by threes). We hypothesized that task-irrelevant changes in shape would disrupt color-location binding memory at short, but not long, study-test intervals, but that this would only be observed when executive resources were available to inhibit the task-irrelevant dimension (i.e., no attention load). Contrary to our predictions, we found that task-irrelevant shape changes disrupted color-location binding memory at all delay intervals (250, 750, 1250, 1750 ms), irrespective of load. These results suggest that feature binding in VWM is sensitive to changes in task-irrelevant properties of objects stored in VWM, contrary to previous findings.

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53.4069 **Shifting feature-based attention in visual short-term memory** Zampeta Kalogeropoulou[1,2,3](zampeta.kalogeropoulou@bccn-berlin.de), Akshay Jagadeesh[4], Sven Ohl[1,2], Martin Rolfs[1,2]; [1]Department of Psychology, Humboldt Universität zu Berlin, Germany, [2]Bernstein Center for Computational Neuroscience Berlin, Germany, [3]International Doctoral Program at the Bernstein Center for Computational Neuroscience Berlin, Germany, [4]Department of Computer Science, University of California, Berkeley, USA

Many everyday tasks require the active prioritisation of one feature among competing ones, both during the selection from the rich sensory input and in visual short-term memory (VSTM) when the relevant information has disappeared from view. Here, we address whether we can change priorities

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in VSTM when, initially, we attended to a different set of features. More generally, does feature-based attention (FBA) independently affect stimulus encoding and maintenance in VSTM? We had observers report from memory the orientation of one of two distributed groups of Gabors (one black, one white), flashed for 150 ms. To manipulate FBA during stimulus encoding, in 60% of all trials, we pre-cued one color 1 s before stimulus onset, indicating the group most likely to be the target (67% validity); in the remaining 40% of trials, the pre-cue was neutral. A retro-cue, displayed 1 s after stimulus offset, then revealed the color of the target orientation (valid, 75%) or did not provide additional information (neutral, 25%). Another second later, we displayed the target group of Gabors (in target color) at a random orientation and observers rotated a knob to adjust their remembered orientation. We fitted each observer's orientation-report distributions using a mixture model comprising target reports, erroneous non-target reports, and random guesses. Valid pre-cues reliably reduced observers' guess rate and increased their report precision (i.e., 1/spread around the target orientation) as compared to neutral ones; invalid pre-cues increased the guess rate and reduced precision. Valid retro-cues did not affect the precision of the report, but further reduced the guess rate, independently of the pre-cue condition. Non-target reports were infrequent (~3%) in all conditions. Thus, FBA had independent effects during stimulus encoding (pre-cuing) and stimulus maintenance in VSTM (retro-cuing). It can change priorities in VSTM, fortifying information that would otherwise be prone to decay.

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53.4070 **The compression of bound features in visual short-term memory** Yuri Markov[1](ikam.mya@gmail.com), Igor Utochkin[1]; [1]National Research University Higher School of Economics, Moscow, Russia

In numerous studies, it is well documented that the visual system exploits regularities of multiple objects for the more efficient perception and storage of large chunks of information, thus struggling the severe limits of processing bottleneck. In terms of information framework, this can be called compression. It was shown that visual short-term-memory (VSTM) uses regularities in object features to compress the data (Brady, Konkle, & Alvarez, 2009). Also, it is likely that VSTM can store features of an object bound together, although at some cost of binding (Fougnie, Asplund, & Marios, 2010; Luck & Vogel, 1997). We tested how compression is carried out for separable features bound in objects. In our experiments, observers memorized the color and orientation of triangles and then, after a 1-second delay following the offset of the triangles, recalled either the color, or the orientation of a probed triangle. There were five conditions: (1) three triangles with all different features, (2) three triangles with different color and identical orientation, (3) three triangles with different orientation and identical color, (4) three triangles with all identical features, (5) one triangle. Using the mixture model algorithm (Suchow, Brady, Fougnie, & Alvarez, 2013; Zhang & Luck, 2008), we estimated the capacity and fidelity of VSTM. We found perfect capacity and same fidelity for both features in the conditions 4 and 5, which shows that observers compressed the information very well. Also, both capacity and fidelity reduced for one of two features when this feature became variable, but not for another one which remained the same (conditions 2 and 3). Finally, when all features were variable (condition 1), we observed some impairment in the capacity and fidelity of both. Overall, our results show that feature compression in VSTM can be performed independently for each dimension, even when those features are bound in objects.

53.4071 **MVPA reveals specialization and generality of sensory-biased regions of frontal cortex** Nishmar Cestero[1](nishmarc@bu.edu), Abigail Noyce[1], Barbara Shinn-Cunningham[2], David Somers[1]; [1]Department of Psychological and Brain Sciences, Boston University, [2]CompNet, Boston University

Discrete visual- and auditory-biased attention structures have recently been identified in caudolateral frontal cortex (Michalka 2015). Two visual-biased regions: superior and inferior precentral sulcus (sPCS and iPCS) are interleaved with two auditory-biased regions: transverse gyrus intersecting precentral sulcus (tgPCS) and caudal inferior frontal sulcus (cIFS). Using multivariate pattern analysis (MVPA), we tested whether structures preferentially active during visual or auditory working memory (WM) contain information about memory content. We collected fMRI while subjects (n = 12) performed visual and auditory 2-back tasks. Visual stimuli were faces (male or female in separate blocks); auditory stimuli were animal vocalizations (cat or dog). Visual- and auditory-biased frontal regions were defined by contrasting visual with auditory WM activation. We performed two cortical surface-based MVPA analyses using the CosmoMVPA toolbox and a support vector machine to test within-modality decodability. Two separate classifiers attempted to categorize visual and auditory WM blocks into stimulus sets (visual: male or female faces; auditory: cat or dog vocalizations). In the first analysis, a whole-brain surface searchlight approach defined 100-vertex circular neighborhoods for each participant. Both visual and auditory classification was better than chance in caudolateral prefrontal cortex, pre-supplementary motor area, and anterior insula. Additionally, visual classification was decoded by activity in intraparietal sulcus, while auditory categories were predicted by superior temporal gyrus and angular gyrus activity. The strong classifier performance in caudolateral frontal cortex led us to further investigate our four frontal, sensory-biased regions, defining them as ROIs for MVPA classification. Classifiers for visual-biased sPCS and iPCS robustly decoded both visual and auditory categories, while auditory-biased tgPCS and cIFS ROIs robustly supported auditory categorization, but only weakly supported visual categorization. These results suggest that visual-biased caudolateral frontal structures may be part of a more domain-general cognitive circuit, while auditory-biased structures may be more domain specialized.

Acknowledgement: CELEST (NSF SMA-OA35976)

53.4072 **Object Representations Guide Visual Short-Term Memory** Breana Carter[1](BCarter0812@gwmail.gwu.edu), Joseph Nah[1], Sarah Shomstein[1]; [1]George Washington University

Successful cognitive functioning requires engagement of visual attention and visual short-term memory (VSTM). There is overwhelming evidence that visual attention and VSTM are highly interrelated, and engage similar regions within the control network (e.g., inferior-parietal sulcus). These similarities led us to hypothesize that both systems may operate under similar constraints. For example, attentional selection is known to be greatly influenced by object representations. Here, we ask whether VSTM is similarly constrained. In Experiment 1, a sample memory array of four differently colored squares briefly appeared on a three-rectangle arrangement. Two squares appeared on the central fixated rectangle (same-object) while the other two squares appeared on one of the two flanking rectangles (different-object). After a 1000ms retention period, a test array appeared and participants determined whether the new set was the same or different. A change occurred on half of the trials. Participants were split into two groups based on VSTM capacity. Object-based modulation of VSTM performance was observed in the high-capacity group, with higher accuracies for detecting a change on the same attended object as compared to when change occurred on the different object. VSTM performance for the low-capacity group was not modulated by object representations. In Experiment 2, we added a cue, highlighting the central object, with an expectation of increasing attentional allocation to the central object. We observed that the addition of a central cue resulted in object-based modulation of VSTM in both the low- and high-capacity groups. Our results suggest that while the attentional system is automatically constrained by object-based representations, the VSTM system shows more flexibility. Mainly, objects constrain VSTM automatically only in high-capacity individuals, suggesting that the use of object-based representations in VSTM could reflect a perceptual strategy. Interestingly, low-capacity individuals can benefit from object-based representations if those representations are made salient.

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53.4073 **Multi-part objects yield no change detection benefit for color and orientation even when parts are unambiguously integrated in the display** Benjamin McDunn[1](bmcdunn@uga.edu), James Brown[1], Ralph Hale[1], Richard Plummer[1]; [1]University of Georgia

Numerous studies have shown that visual short-term memory can store more task relevant features when they are integrated into a single object than when they appear as separate single-feature objects (Luck & Vogel, 1997; Olson & Jiang, 2002). For instance, four colors and four orientations can be encoded more efficiently when they appear as four colored and tilted bars than eight spatially separate single-feature objects. In contrast to these findings, mixed results have been found when features appear as different parts of an object, with very few experiments showing a clear performance benefit when features are organized as multi-part objects versus spatially dispersed single-feature objects (Davis & Holmes, 2005; Delvenne & Bruyer, 2004; Xu, 2002). Some researchers have suggested multi-part object integration is not mandatory due to the potential ambiguity of the display (Balaban & Luria, 2015; Luria and Vogel, 2014). For example, an oriented white bar across the middle of a red circle could be interpreted as two objects, a white bar occluding a red circle, or as a single two-colored object. We tested whether or not multi-part objects could be integrated in memory under less ambiguous conditions. Change detection performance

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for colored circles with an oriented white bar across the middle was compared to performance for colored spheres with an oriented white stripe across the middle. Luminance shading and linear perspective on the spheres indicated that the two features were part of one continuous surface on the object. These two conditions were also compared to a condition in which colored circles and orientated white bars were spatially separated and a condition in which the circles and bars partially overlapped. We found no performance differences between conditions suggesting multi-part objects cannot be integrated in visual short-term memory even when they appear on a continuous surface and are unambiguously connected.

53.4074 Effects of previewing intrinsic color-shape conjunction on temporal illusory conjunctions

Jun Saiki[1](saiki.jun.8e@kyoto-u.ac.jp), Meiko Shibata[1]; [1]Graduate School of Human and Environmental Studies, Kyoto University

In visual memory, bindings of shape with its figure color (intrinsic binding) and with its background color (extrinsic biding) are qualitatively different. We investigated effects of intrinsic and extrinsic bindings in visual memory on perceptual identification of shape-color binding. Participants previewed a sample display composed of a nonsense figure with colors for 1 s, followed by an RSVP sequence. In Experiment 1, participants previewed a figure with both intrinsic and extrinsic colors, and detected the sample figure from the RSVP sequence. The RSVP sequence contained either intrinsic or extrinsic colors alone. The target figure had the color of matched location of the sample (match condition), the color of mismatched location of the sample (mismatch condition) or a color not presented in the sample (different condition). Compared with the different condition, the detection performance was higher in the match and mismatch conditions with the intrinsic and extrinsic trials, respectively, suggesting that only intrinsic color of the sample display facilitated the detection of sample figure. To investigate the effect of preview on temporal illusory conjunctions, we showed participants a preview with only intrinsic color and asked them to identify the intrinsic color (Experiment 2) and extrinsic color (Experiment 3) of the target shape. Overall, the post-target illusory conjunction was more frequent than the pre-target illusory conjunction. This pattern was modulated by the sample display in two ways. First, when the sample color was presented one item prior to the target, the pre-target illusory conjunction significantly increased for both intrinsic and extrinsic sequences. Second, only for the intrinsic sequence, the intrinsic color presented with the target shape significantly reduced the illusory conjunction. Intrinsic colors facilitate the detection of the target shape, increase pre-target illusory conjunction regardless of figure/ground distinction, and rescue from post-target illusory conjunctions exclusively at the figural location.

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53.4076 Role of Attention in the Temporal Dynamics of Visual Working Memory Processing

Jane Jacob[1](j.jacob@westminster.ac.uk), Christianne Jacobs[1], Bruno Breitmeyer[2], Juha Silvanto[1]; [1]Department of Psychology, University of Westminster, UK, [2]Department of Psychology & Center for Neuro-Engineering and Cognitive Science, University of Houston, USA

To investigate the role of attention in the time course of visual working memory, a memory scanning experiment was conducted with three conditions: control, neutral cue and spatial cue. On each trial, a memory array of 4 items (simple geometric shapes) preceded a probe item at varying inter-stimulus intervals (ISIs). In cued conditions, either a neutral or informative spatial cue was presented 300 ms before the probe onset. The neutral cue pointed toward all four locations of the memory array, whereas the spatial cue pointed in the direction of one of the 4 array items, either matching or mismatching the probe. In all conditions, observers reported whether or not the probe differed from an item in the memory array. Response reaction times were collected, and comparison effects (CEs) were computed by subtracting average reactions times for matched from mismatched memory array-probe pairings. Similar to previous findings (Jacob, Breitmeyer & Treviño, 2013), CEs in the control condition varied systematically across ISIs, likely reflecting fluctuations in attention and working memory content. The CEs in the spatially-cued condition followed the same temporal pattern as the control condition, but the amplitude of the fluctuations was dampened, and the CEs diminished by 4000 ms. As expected, the spatial cue utilizes spatial attention to make a judgement between the cued item and the probe, reducing the amount of information that needs to be maintained in memory. This is likely to reflect spatial attention overriding the effects of attention to WM content. In contrast, the CEs in the neutral-cued condition showed CE fluctuations with higher amplitude for later ISIs. The neutral cue enhances processing of the content of working memory, amplifying CEs as ISIs increase. Our results suggest that attention plays a role in determining stages of information processing in working memory.

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53.4077 The influence of object rotation on visual serial dependence

Patience Stevens[1](ps910@mit.edu), Jason Fischer[1,2]; [1]McGovern Institute for Brain Research & Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]Department of Psychological and Brain Sciences, Johns Hopkins University

Recent studies have shown that visual perception is serially dependent — consistently biased toward input from the recent past — which stabilizes our visual experience in the face of noisy input. Several characteristics of visual serial dependence suggest that it may be tuned to the dynamics of the natural world, operating selectively across inputs that likely arose from the same physical object. For example, stimuli that move a large distance between trials are released from serial dependence, consistent with the fact that real-world objects do not spontaneously jump to entirely new locations. Real-world objects also do not undergo sudden large rotations on the retinae; rather, they undergo small, smooth rotations, often due to head and body movements. Is visual serial dependence tuned to object rotation, occurring most strongly across stimuli with small rotations, as expected of natural visual input? Here, we tested the rotational tuning of serial dependence using a shape judgment task. Observers saw a sequence of shapes drawn randomly from a morphed shape continuum, each presented with a random rotation (500ms presentation, one stimulus every ~5 seconds). On each trial, observers reported the shape they just saw using an adjustment response. We found that the perceived shape on a given trial was attracted toward the shape seen on the previous trial (serial dependence). The strength of this attraction did not fall off monotonically with increasing stimulus rotation between trials as we had predicted. Rather, the serial dependence from one trial to the next was governed by the pixel-wise image similarity of successive stimuli. Our results suggest that serial dependence is tolerant to object rotations, in contrast to its systematic tuning to position changes. In the face of object rotation, low-level image similarity is a key determinant of the strength of serial dependence across successive inputs.

53.4078 Perceptual stability without working memory

Kathy Zhang[1](kathy.zhang@berkeley.edu), Alina Liberman[2], David Whitney[1,2]; [1]Department of Psychology, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley

Perceptual stability is a critical problem for the visual system because visual information that reaches the eyes is often noisy and discontinuous over time due to changes in illumination or viewpoint, among others. A proposed solution to this problem is the continuity field, a mechanism that promotes perceptual stability by generating serially dependent appearance – making similar objects nearby in space and time appear more alike than they actually are (Fischer and Whitney, 2014; Cicchini, et al., 2014; Liberman et al., 2014). The visual system seems to therefore sacrifice accuracy for the sake of stability; however, such a mechanism could quickly reduce accuracy to a level that is maladaptive. In the current study, we ask if the continuity field can accommodate the competing goals of visual accuracy and stability, depending on the demands of a particular task. To test this, we measured the strength of serial dependence when subjects performed a task with a high working memory load. Subjects viewed a sequence of random target faces drawn from a continuous distribution of morphed faces. After each target face, subjects were cued to adjust a random test face to match the identity of the target face they just saw or the target face on the previous trial (high working memory load). In another condition, subjects were cued to match only the most recent face (low working memory load). We found that the strength of serial dependence was diminished in the trials with a high working memory load compared to the trials with a lighter load. When the task required working memory for past objects, the continuity field adjusted to reduce serially dependent perception. This result suggests that the continuity field does not depend on working memory and can balance the need to represent images accurately with the need to stabilize perception.

53.4079 Statistical learning of movement

Joan Ongchoco[1](joan.ongchoco@gmail.com), Stefan Uddenberg[2], Marvin Chun[2]; [1]Division of Social Science, Yale-NUS College, [2]Department of Psychology, Yale University

The environment is dynamic, but objects move in predictable and characteristic ways, whether a dancer in motion, or a bee buzzing around in flight. Complicated sequences of movement are comprised of simpler motion trajectory elements chained together. But how do we know where one trajectory ends and another begins, much like we parse words from continuous

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streams of speech? As a novel test of statistical learning (Fiser & Aslin, 2002), going beyond prior work that focused on gesture processing and biological motion (e.g., Roseberry et al., 2011), we explored the ability to parse meaningless movement sequences into simpler element trajectories. We developed a basic "alphabet" of basic elements of movement that can be seamlessly strung together into more complicated motion sequences. Across three experiments—in which continuity of motion was steadily increased—observers viewed a single dot as it moved along simple sequences of paths, and were later able to discriminate these sequences from novel ones shown at test. In Experiment 1, a single disc followed a trajectory away from the center and then disappeared; it then reappeared at the center of the video frame and traced another trajectory. In Experiment 2, the disc first traveled away from, and then back toward, the center of the video frame for each trajectory in the sequence, producing a percept of continuous motion around the center. In Experiment 3, the disc traveled around the screen without returning to a given point at any time. With at least 12 participants in each experiment, mean recognition performance for repeated trajectories was significantly above chance at 60%, 69%, and 58% for the three experiments respectively. These results suggest that observers can automatically extract regularities from continuous movement—an ability that may underpin our capacity to learn more complex biological motions, as in sport or dance.

53.4080 Interactions Between Visual Working Memory and Selective Attention in Adults, Control Children, and Survivors of Pediatric Cancer Melissa Trevino[1](mtrevino@uh.edu), Bruno Breitmeyer[1]; [1]Psychology, College of Liberal Arts and Social Sciences, University of Houston

Studies have shown that when visual working memory (VWM) reaches its processing limit when maintaining a substantial amount of information, its cognitive resources are depleted for use in other cognitive functions, such as selective attention (SA) (de Fockert et al., 2001). We investigated how VWM affects SA across and within spatial and feature-based information processing in adults (18+), typically developing children (10-18yrs.) and survivors of pediatric acute lymphoblastic leukemia (ALL) (10-18yrs.). ALL survivors were included to assess cognitive outcomes of cancer treatment protocols. A dual-task paradigm, combining a VWM task and a flanker task assessing visual attention, was used. Adults ran in 18 dual-task conditions: varied by VWM load (1, 3, 5 items), VWM feature/task (color, shape, location) and of the flanker feature/task (color, shape). Adults also ran in 9 corresponding single-task VWM control conditions and 2 single-task flanker control conditions. Both child groups ran in 6 dual-task conditions of only a VWM load of 3 items but varied in VWM feature/task (color, shape, location) and of the flanker feature/task (color, shape). Child participants also ran in 3 single-task VWM control conditions and 2 single-task flanker conditions. Results reveal maintenance of information in VWM is susceptible to interference from the concurrent SA task for all three groups. VWM capacity estimates, K, decreased when a VWM task was preceded by a SA task compared to a single VWM task and this decrease was greater in both child groups than adults (see Figure 1). These interference effects were found to be feature specific for all groups. For the SA tasks, all three groups appeared to be immune to interference from a concurrent VWM task, since flanker effects (difference between incongruent and congruent reaction times) did not vary across condition (VWM single-task vs. VWM dual-task).

53.4081 Perceptual averaging of scientific data: Implications of ensemble representations for the perception of patterns in graphs Stefan Uddenberg[1](stefan.uddenberg@yale.edu), George Newman[2], Brian Scholl[1]; [1]Dept. of Psychology, Yale University, [2]School of Management, Yale University

One of the most prominent trends in recent visual cognition research has been the study of ensemble representations, as in the phenomenon of perceptual averaging: people are impressively accurate and efficient at extracting average properties of visual stimuli, such as the average size of an array of objects, or the average emotion of a collection of faces. Here we explored the nature and implications of perceptual averaging in the context of a particular sort of ubiquitous visual stimulus: graphs of numerical data. The most common way to graph numerical data involves presenting average values explicitly, as the heights of bars in bar graphs. But the use of bar graphs also leads to biased perception and reasoning, as observers implicitly behave as if data are more likely to be contained within the bars themselves, even when they depict averages (as in the so-called 'within-the-bar bias', perhaps due to object-based attention). Here we tested observers' ability to perceive and remember average values via perceptual averaging when they viewed entire distributions of values. Observers had to extract and report (via mouse clicks) the average values of two distributions, depicted either as bar graphs or as 'beeswarm plots' (a kind of one-dimensional scatterplot, in which each datapoint is depicted by a non-overlapping dot — with no explicit representation of the average value). Observers were surprisingly accurate at extracting average values from beeswarm plots. Indeed, observers were just as accurate at reporting averages from visible beeswarm plots as they were when simply recalling the heights of bars from bar graphs. Even reports of average values from beeswarms made from memory were highly accurate (though not as accurate as when the beeswarms were visible). These results collectively demonstrate that perceptual averaging operates efficiently when viewing scientific data, and could be exploited for information visualization.

Temporal Processing: Timing and time perception

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

53.4083 Measurement and manipulation of temporal weighting in perceptual decision-making Aaron Levi[1,2,3](alevi@utexas.edu), Leor Katz[1,2,3], Jacob Yates[1,2,3], Alexander Huk[1,2,3,4]; [1]Institute for Neuroscience, UT Austin, [2]Center for Perceptual Systems, UT Austin, [3]Department of Neuroscience, UT Austin, [4]Department of Psychology, UT Austin

Competing models of decision-making invoke distinct mechanisms underlying the integration of sensory evidence. Prior work has used stimulus and response timing to probe this mechanism. Here, we adopt a complimentary strategy in which we psychophysically measure and manipulate the time course of strategic weighting of sensory information used to inform decisions. Observers performed a motion discrimination task in which each trial comprised seven discrete epochs in time (i.e. seven "motion pulses") where each can have distinct motion coherence. On each trial, the observer reported net leftward or rightward perceived motion. Trials contained varied motion strength, with a subset containing purely directional noise. These noise trials were used for reverse correlation analysis, in which the choice was correlated with the motion strength in each pulse, yielding a temporal kernel describing the observer's temporal weighting strategy. Baseline kernels varied across both human and monkey observers, but on average demonstrated preferential weighting of early pulses, as often observed in other work. After measuring an observer's baseline temporal weighting, we attempted to change their strategy by modifying the likelihood of high coherence at different times during non-noise trials. By biasing strong motion to occur late in the stimulus, we were able to shift early weighting to late weighting— thus demonstrating direct control over the decision strategy. Although the time course of stimulus weighting can be taken as evidence for a particular type of integration mechanism, many models of decision-making are often flexible enough to account for many patterns of temporal stimulus weighting. Our ability to manipulate the time course of weighting suggests that it should be thought of as a malleable strategy that observers can flexibly adapt to stimulus statistics. This approach will be used in ongoing electrophysiological experiments as a causal manipulation to probe the temporal structure of choice-correlated neuronal activity.

53.4084 The perceived duration of global motion in random dot kinematogram (RDK) displays Doga Gulhan[1](doga.gulhan@boun.edu.tr), Inci Ayhan[1,2]; [1]Cognitive Science Program, Bogazici University, Istanbul / Turkey, [2]Department of Psychology, Bogazici University, Istanbul / Turkey

Apparent duration can be manipulated in a local region of visual field by adaptation to motion or flicker (A. Johnston, D. H. Arnold, & S. Nishida, 2006; I. Ayhan, A. Bruno, S. Nishida, & A. Johnston, 2009). Duration compression occurs in the absence of changes in temporal frequency or speed, implying separate encoding of duration and temporal frequency. Here we examine the effects of variation in the temporal features of local signals on the apparent duration of global motion using RDK patterns at 50% coherence level (with noise dots having a vector sum speed of 0deg/s). In different conditions, the lifetime of individual dots were either fixed at 150ms or varied between 50-250ms as randomly selected from a normal distribution. Additionally, the effect of variation in the speed of individual dots had also been manipulated to target fast and slow global motion mechanisms. In blocked trials of a 2-AFC task, subjects compared the duration of a comparison stimulus (variable duration across trials; 150ms dot-life; 2.5 or 9deg/s dot speed) to the duration of a standard stimulus (fixed at 550ms across trials) with individual dots either having fixed (150ms) or variable (50-250ms) dot-life and fixed (2.5deg/s or 9deg/s) or variable (1-4deg/s

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or 6-12deg/s) speeds. The perceived duration was defined as the point of subjective equality of the psychometric function. Across all speed conditions, we found a relative duration expansion (10%) in conditions where the lifetime of dots had been variable in comparison to those where the dot lifetimes was fixed, whereas varying the speed of individual dots around the same average speed for slow (2.5deg/s vs 1-4deg/s) and fast (9deg/s vs 6-12deg/s) ranges had no relative effect on the apparent duration. Control experiments have shown that neither changes in perceived speed nor the allocation of attentional resources can explain this temporal expansion.

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53.4085 **Please wait while this abstract finishes loading: Subjective time dilation while viewing progress bars is influenced by perceived event structure** Yi-Chia Chen[1](yi-chia.chen@yale.edu), Brian Scholl[1]; [1]Dept. of Psychology, Yale University

Our impression of how long something lasts is a function not only of its objective duration, but also of how the mind carves it into discrete events: a series of short talks, for example, may seem shorter than one long talk. This has been explained via the event-based nature of working memory: when you encounter an event boundary, working memory is 'flushed' to prepare for the next event. Greater event segmentation may thus lead to shorter perceived durations, due to the flushing of details from memory. This suggests, however, that segmentation could influence perceived duration very differently in stimuli that possess few details to begin with. We manipulated perceived event segmentation in simple stimuli that are frequently encountered while waiting for digital content: observers viewed a progress bar — a long rectangle that was gradually filled — while waiting for an online survey to load. The bar was either featureless or was subdivided via static lines into equivalent segments. In addition, the bar either filled at a constant speed, or paused briefly at regular intervals. Once complete, observers were unexpectedly asked to reproduce the bar's duration. Progress bars seemed to last longer when they paused at static marks (perceived as multiple distinct motions) compared to when they paused without any marks (perceived as a single stuttered motion). This effect disappeared, however, when the progress bar filled smoothly (when the marks didn't induce segmentation). Thus event segmentation dilates perceived durations during simple events: more events seem to last longer than fewer events when there are no details to flush from memory. These results reveal how our experience of continuous time is a function of how our minds divide it into discrete episodes — and also how very simple manipulations can make a big difference to perceived durations in familiar contexts.

53.4086 **Modality-dependent and modality-independent nature of central tendency in time perception** Yuki Murai[1,3](ymurai@fechner.c.u-tokyo.ac.jp), Yuki Hashimoto[2,3], Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo, [2]Graduate School of Interdisciplinary Information Studies, The University of Tokyo, [3]The Japan Society for the Promotion of Science

When stimuli of various durations are presented in an intermixed fashion, longer durations are underestimated, and shorter durations are overestimated. This phenomenon, called the central tendency, suggests that our brains optimally encode stimulus duration based on the likelihood measured by the timing system and the prior knowledge about the distribution of the stimulus duration. Our study aims to examine how stimulus modality affects this optimal encoding of time across different timescales. Recent studies have revealed that two distinct systems are recruited in the perception of sub- and supra-second durations. Sub-second timing is subject to local sensory processing while supra-second timing depends on relatively centralized mechanisms. We hypothesized that the central tendency occurs in a modality-dependent manner for the sub-second timing, which depends on processing within each sensory system. In the experiment, subjects were asked to reproduce sub-second (400–600 ms) or supra-second (2000–3000 ms) durations defined by the visual or auditory stimulus. Subjects performed four experimental blocks, in each of which stimulus modality and timescale of stimulus durations were fixed. The reproduced durations were linearly regressed to the stimulus durations, and the slope of the linear regression was used as an index for the magnitude of the central tendency. The central tendency of reproduced durations was observed in all conditions except auditory sub-second timing. For the sub-second timing, the magnitude of the central tendency was significantly larger for visual durations compared to auditory durations, while such a difference was not observed in the supra-second timing. Furthermore, the reproduced durations for visual and for auditory stimuli were significantly correlated across individuals for the supra-second timing. These results suggest that the modality-dependent sensory timing systems in the sub-second range are involved in the optimal encoding of time. Modality dependency of timing is discussed in relation to the Bayesian framework of time perception

53.4087 **Time dilation in a jittering motion perceived in a stationary stimulus** Ikuya Murakami[1](ikuya@l.u-tokyo.ac.jp), Shunsuke Aoki[1], Akitoshi Kawano[1], Masahiko Terao[1,2]; [1]Department of Psychology, the University of Tokyo, [2]The Research Institute for Time Studies, Yamaguchi University

It is well known that a moving stimulus appears to last longer. Proposed determinant factors of this temporal illusion include temporal frequency, speed, attention, cortical expenditure, etc., and recent works have demonstrated that illusory dilation occurs with the perceived speed of a moving plaid as well as that of a moving display whose motion is enhanced by simultaneous motion contrast. If perceived rather than physical motion has a stronger impact on time perception, illusory dilation may occur even in a physically stationary stimulus that is subjectively moving due to a motion illusion. To test this hypothesis, we took advantage of a vivid motion illusion termed visual jitter, namely, after adaptation to dynamic random noise, a physically stationary stimulus in a previously unadapted region appears to move in random directions, which reflect the retinal image motions concomitant with the observer's own fixational eye movements upon fixation of the stationary stimulus. Using a matching method, we quantified the apparent duration of a stationary stimulus for a fixed duration while the observer was experiencing the jitter aftereffect there. As a negative control, the apparent duration of the same stationary stimulus without adaptation was also measured. As a positive control, we further measured the apparent duration of a stimulus that was physically jittering on the monitor. We found that for a majority of observers, neither the physically jittering stimulus nor the subjectively jittering stimulus appeared to dilate, but for a substantial fraction of observers, both the physically jittering stimulus and the subjectively jittering stimulus appeared to last longer than the physically as well as subjectively stationary stimulus. In other words, those observers who experienced dilation in physical jitter also experienced dilation in perceived jitter. These results strengthen the idea that perceived motion is one of the most influential determinant factors of perceived duration.

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53.4088 **Neural correlates of illusory discrete perception: an EEG study** Ryohei Nakayama[1,3](nryohei@l.u-tokyo.ac.jp), Isamu Motoyoshi[2], Takao Sato[1]; [1]Department of Psychology, Tokyo University, [2]Department of Life Sciences, Tokyo University, [3]Research Fellow of Japan Society for the Promotion of Science

In a previous study, we reported that when spatial window of a Gabor moved constantly whereas the carrier grating stayed still or drifted in the opposite direction, the whole stimulus appeared to move only intermittently with a constant temporal rate of 4-6 Hz regardless of the speed of stimuli (Nakayama et al., VSS 2014). We interpreted that this illusory saltation is essentially a consequence of periodical resets of an increasing discrepancy in the spatial position signals between luminance-defined grating motion and contrast-defined window, but that the apparent rhythm of saltation is determined by a neural mechanism that updates the perceptual awareness at a fixed temporal rate of 4-6 Hz. Similar temporal fragmentation of perception at 4-6 Hz has been reported among motion-blind patients (Hess et al., 1989), implying that this rhythm is related with the temporal continuity of perceptual awareness. To investigate the neural basis of this illusory discrete perception, we here examined EEG signals during the observation of illusion. The analyses revealed that theta-band power was significantly attenuated focusing around parietal-occipital regions when participants observed stimuli that caused illusory discrete motion as compared to when they observed smoothly moving stimuli. We suggest that these parietal theta components may reflect a clock-like mechanism which underlies the temporal continuity of conscious perception.

53.4089 **Flickering task-irrelevant distractors dilate the perceived duration of a target not on the retinotopic coordinate but on the cortical coordinate** Miku Okajima[1](okajima@fechner.c.u-tokyo.ac.jp), Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo

The duration of a flickering stimulus is perceived as longer than that of a stable stimulus. This kind of phenomenon, also known as time distortion, has been widely used in studies of time perception. Although many hypotheses about time encoding have been reported, including a spatially specific clock system and the general magnitude system, recent electrophysiological studies have shown that interval information can be encoded by neural oscillations. In this study, we investigated whether neural oscil-

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lations can explain time dilation induced by flickering visual stimuli. During the experiments, subjects were asked to reproduce the duration of the target stimulus (450, 650, or 850 ms) while the temporal frequencies of the target or distractors were modulated. In experiment 1 (N = 9), the distractors appeared before the target onset and disappeared after the target offset. The reproduced target duration was longer when either the target or distractor flickered compared to when either one was stable. In addition, a flickering distractor ipsilateral to the target induced longer dilation than a flickering distractor contralateral to the target. Flickering distractors caused longer time dilations than flickering targets. In experiment 2 (N = 9), similar durations were used for both the distractors and the target. Although flickering distractors still induced time dilation, dilation induced by flickering distractors was shorter than that induced by the flickering target. There are three important findings from this study. First, flickering task-irrelevant distractors distort the perceived duration of target stimuli. Second, the amount of dilation depends on the distance between cortical areas, which correspond to stimulus locations. Finally, longer-duration flickering distractors caused longer time dilation. These findings support the hypothesis that time information is encoded by neural oscillations.

Acknowledgement: KAKENHI-251190032, 24330208

53.4090 **Time Perception and Stimulus Response Compatibility** D. Alexander Varakin[1](donald.varakin@eku.edu), Amanda Renfro[2], Jason Hays[2]; [1]Department of Psychology, Eastern Kentucky University, [2]Department of Psychology, Florida International University

The current experiments tested if stimulus response compatibility affects duration judgments. Participants performed a temporal bisection task, judging on each trial whether stimulus' duration was closer to pre-learned short (400ms) or long (1600ms) standards. In each experiment, compatibility between stimuli and responses was manipulated. Stimuli were squares that appeared on the left or the right side of the computer monitor, or arrows that pointed left or right. Participants used left and right button presses to judge duration. Response mapping was counterbalanced: half of participants used a right-hand key for "long" judgments and a left-hand key press for "short" judgments, and vice versa for remaining participants. In Experiments 1 and 2, the stimulus appeared on the right or left side of the monitor on each trial. Responses were unspeeded in Experiment 1, and speeded in Experiment 2 (participants had to respond within 800ms of stimulus offset). In Experiments 3 and 4, stimuli were arrows pointing left or right. In Experiment 3, participants could respond immediately after stimulus offset, but in Experiment 4, half of the participants had to wait 2000ms after stimulus offset before responding. In all experiments, long-compatible stimuli reliably elicited long judgments at shorter durations than short-compatible stimuli. In other words, if the right-hand key was mapped to long judgments, squares on the right and arrows pointing right had a greater subjective duration than squares on the left or arrows pointing left. This pattern was reversed when the left-hand key was mapped to long judgments. The effect does not seem to be driven by transient activation of compatible motor responses, because it was observed for both unspeeded (Experiment 1) and delayed (Experiment 4) responses. Overall, these results are consistent with the idea that time perception is affected by stimulus response compatibility.

53.4091 **Time in the eyes: Covariant temporal compression and pupil constriction to impending collision** Tao Zhang[1](taozhang@psych.ac.cn), Yang Wang[1,2], Peijun Yuan[1,2], Shenbing Kuang[1], Yi Jiang[1,3]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China, [2]University of Chinese Academy of Sciences, Beijing, China, [3]CAS Center for Excellence in Brain Science and Intelligence Technology, China

Time perception can not only be influenced by the physical properties of external stimuli but also the observer's internal mental states. It remains unclear, though, whether the threatening information conveyed by visual collision can influence subjective time perception. Here we simulated an impending-collision scenario by rendering a looming ball in a virtual 3D space, and observers were asked to judge the duration of the looming ball which targeted at the center of their head (direct hit), at their fringe (marginal hit) or off their head (miss). Results showed that the looming ball in the two hit conditions was perceived as significantly shorter in duration relative to that in the miss condition. By directly comparing the effects with looming vs. receding balls, we further showed that the observed time compression effect could be attributed to the perceived threat information as well as the moving distance of visual stimuli. More intriguingly, the collision-induced threatening information reduced the pupil size at a short latency (500 ms) post stimulus onset, and the magnitude of the pupil constriction was positively correlated with the strength of the temporal compression effect. Together these findings provide compelling evidence that threatening information shortens perceived duration of visual stimuli and evokes pupil constriction responses, and highlight a covariant relationship between the psychological and physiological responses in the visual perception of ecologically salient information.

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Perceptual Learning: Neural mechanisms

Tuesday, May 17, 8:30 am - 12:30 pm

Poster Session, Pavilion

53.4092 **Visual BOLD response in late-blind subjects with Argus II retinal prosthesis** Elisa Castaldi[1](elisa.castaldi@gmail.com), Marco Cicchini[2], Laura Cinelli[3], Michela Tosetti[4], Stanislao Rizzo[3], Maria Morrone[1]; [1]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy, [2]CNR Neuroscience Institute, Pisa, Italy, [3]Azienda Ospedaliero-Universitaria Careggi, SOD Oculistica, Florence, Italy, [4]Department of Developmental Neuroscience, Stella Maris Scientific Institute, Pisa, Italy

The recent advance in retinal prosthesis technologies generates hope for partially restoring vision to blind people with retinal pathologies. However, these strategies require the visual system downstream of the retinal circuitry to be capable of transmitting and elaborating visual signals. We studied plastic remodeling in late blind subjects implanted with Argus II Retinal Prosthesis. We assessed the visual function of a group of 7 blind patients before and after implantation. We measured motion direction discrimination, as well as detection of the same stimuli presented stationary to the operated and un-operated eyes in 2AFC design. We also recorded BOLD responses before and after the implant in four subjects in response to full-field flashing stimuli (1Hz) alternated with rest periods of dark. When the subjects used the prosthetic implant, detection discrimination improved over time, but not direction discrimination which remained at chance. No subject showed any improvement of vision in either eye when not aided by the Argus II. Before the implant the BOLD activity in the primary visual area and the putative LGN was very weak or absent, after surgery the response to visual inputs was enhanced. Interestingly this recovery was ipsilateral to the implant, implying that the neural changes are strictly correlated with the stimulation site. Given the evidence that the electrodes stimulate ganglion cells axons mainly from temporal hemiretina (Fine, Boynton Phil. Trans. R. Soc. B, 2015), our results suggest that local electrical stimulation may induce trophic factors and cause the enhancement in the activity of the LGN and V1 that receive afferents from temporal hemiretina. This is the first study tracking the neural changes of visual areas in patients after retinal implant and revealed a capability to respond to restored visual input even after years of deprivation.

53.4093 **Perceptual learning modifies the functional specializations of visual cortical areas** Fang Fang[1,2,3,4](ffang@pku.edu.cn), Nihong Chen[1,2,3,4], Peng Cai[1,2,3,4], Tiangang Zhou[5], Benjamin Thompson[67]; [1]Department of Psychology and Beijing Key Laboratory of Behavior and Mental Health, [2]Key Laboratory of Machine Perception (Ministry of Education), [3]Peking-Tsinghua Center for Life Sciences, [4]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing 100871, P.R. China, [5]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing 100101, P. R. China, [6]School of Optometry and Vision Science, University of Waterloo, Waterloo, ON N2L 3G1, Canada, [7]School of Optometry and Vision Science, University of Auckland, Auckland, New Zealand

Training can improve performance of perceptual tasks. This phenomenon, known as perceptual learning, is strongest for the trained task and stimulus, leading to a widely accepted assumption that the associated neuronal plasticity is restricted to brain circuits that mediate performance of the trained task. Nevertheless, learning does transfer to other tasks and stimuli, implying the presence of more widespread plasticity. Here, we trained human subjects to discriminate the direction of coherent motion stimuli. The training effect substantially transferred to noisy motion stimuli. TMS and fMRI measures showed that, before training, visual cortical areas V3A and MT+ made causal and dissociable contributions to the processing of coherent and noisy motion, respectively.

After training, the contribution of MT+ to the processing of noisy motion diminished and was superseded by V3A. Our results suggest that learning can modify the inherent functional specializations of visual areas and dynamically reweight their contributions to perceptual decisions.

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53.4094 **Participants with central vision loss show stronger resting state functional connectivity between V1 and frontal and parietal regions** Kristina Visscher[1,2,4], Wesley Burge[2], Matthew Defenderfer[1], Rodolphe Nenert[3], Dawn DeCarlo[4], Lesley Ross[5]; [1]Department of Neurobiology, University of Alabama, Birmingham, [2]Department of Psychology, University of Alabama, Birmingham, [3]Department of Neurology, University of Alabama, Birmingham, [4]Department of Ophthalmology, University of Alabama, Birmingham, [5]Department of Psychology, Pennsylvania State University

Macular degeneration (MD) results in reduced central vision and can be debilitating; impairing tasks of daily living such as reading, driving and recognizing faces. However, most patients with MD develop the ability to use peripheral vision for many tasks of daily living. We are interested in understanding how top-down control of visual cortical circuitry influences this process. Here, we address this question by examining functional connectivity between retinopically distinct parts of V1 and the rest of cortex. Using resting BOLD fMRI in MD patients and age, gender, and education-matched controls, we measured functional connectivity between different eccentricity bands within primary visual cortex to other regions within the cortex. V1 regions were defined based on individual anatomy, and non-V1 regions were defined based on published parcellation schemes. Local connectivity between sectors of V1 representing different eccentricities was stronger in Controls than in MD participants, consistent with Controls' more frequent integrated use of different parts of vision. Differences in connectivity to other parts of cortex depended on the eccentricity within V1. Generally, the strength of V1 connectivity to frontal and parietal areas was stronger in MD patients than controls. This finding is consistent with the hypothesis that MD participants develop stronger top-down control of visual information and will inform future work refining this hypothesis.

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53.4095 **The distributed neural basis of visual expertise in different expert groups** Farah Martens[1](farah.martens@ppw.kuleuven.be), Christine van Vliet[1], Hans Op de Beeck[1]; [1]KULeuven

Despite earlier studies and intensive debate, the neural basis of visual learning in the context of real-world expertise is still unclear. Different hypotheses have been proposed, including (i) the expertise hypothesis, focusing on the fusiform face area (FFA) as the center of all expertise-related neural changes; (ii) the informativeness hypothesis, predicting that the extent to which a region's sensitivity is altered by expertise depends on its informativeness for the specific domain of expertise; and (iii) the interactive view, predicting widespread changes within and beyond the visual system. To compare domains of expertise for which different brain regions are informative, we included 20 ornithologists (living objects of expertise), 17 mineralogists (experts in nonliving objects) and 20 control participants in an fMRI experiment. Participants were, among others, presented with images of birds and minerals. Multi-voxel pattern analyses showed significantly distinct neural representations of objects of expertise between the three groups of participants. These distinctions were present in low level and high level visual brain regions, as well as across the whole brain, indicating very widespread effects of expertise. By applying univariate region of interest analyses we demonstrated that ornithologists showed significantly increased activation for birds in FFA, parahippocampal place area (PPA), lateral occipital complex (LOC) and 'living' and 'nonliving' regions. So expertise effects were found in as well as beyond informative brain regions. By contrast, no significant expertise effects were found for mineralogists in any of these functionally defined regions, showing that in mineralogists the distributed changes are not associated with strong local effects. These results suggest very distributed effects of expertise in both expert groups, which is more in line with the interactive view than with the expertise and informativeness hypotheses.

Acknowledgement: ERC

53.4096 **Neurophysiological mechanisms of experience-dependent perceptual biases using concurrent EEG-fMRI recordings** Nathan Petro[1](npetro@ufl.edu), L. Forest Gruss[1], Siyang Yin[2], Haiqing Huang[2], Vladimir Miskovic[3], Mingzhou Ding[2], Andreas Keil[1]; [1]Department of Psychology, Center for the Study of Emotion and Attention, College of Liberal Arts & Sciences, University of Florida, [2]J. Crayton Pruitt Family Department of Biomedical Engineering, Herbert Wertheim College of Engineering, University of Florida, [3]Department of Psychology, Harpur College of Arts & Sciences, Binghamton University

Motivationally relevant compared to irrelevant stimuli show measurable biases in sensory systems. Neurophysiologically, biases have been demonstrated in single-neurons as well as neural mass activity in sensory cortex. One hypothesis states that this modulation of sensory neurons is driven by re-entrant projections from anterior cortical and subcortical structures, but limited empirical evidence exists to support this hypothesis. To address this limitation in the literature, the current project simultaneously collected BOLD and EEG, utilizing their spatial and temporal resolutions, in addition to electrocardiography during a classical conditioning paradigm in which the orientation of grating stimuli (i.e. the conditioned stimulus, CS) predicted the presence (CS+) or absence (CS-) of a cutaneous electric shock (i.e. the unconditioned stimulus, US). Phase reversal of the gratings elicited a steady-state visual evoked potential, which was used to estimate stimulus related visual cortical activity on a single-trial basis. CS+ relative to CS- trials during US pairing were associated with increased ssVEP amplitude, greater heart-rate deceleration, and greater BOLD activation in primary visual, anterior insular, and temporal cortices bilaterally. Modeling BOLD activity using the single-trial ssVEP indices showed specific BOLD-ssVEP coupling in primary and extended visual cortex over all trials, and CS+ relative to CS- specific activation in the calcarine and dorsolateral prefrontal cortices. BOLD signals in bilateral amygdala showed CS+ specific ssVEP coupling early during US pairing. These results suggest that visual cortical responses are amplified as a function of motivational relevance, and that anterior structures relate to fluctuations in visual cortical activity. Future analyses may test the extent to which these extra-visual cortical sites are functionally related visual cortical engagement and if any temporal pattern exists among the engagement of these structures.

53.4097 **The role of the perirhinal cortex in tactile perception and memory in the blind** Laura Cacciamani[1](lcacciamani@ski.org), Lora Likova[1]; [1]The Smith-Kettlewell Eye Research Institute

This study is the first to investigate the neural underpinnings of tactile object familiarity in the blind during both perception and memory. In the sighted, the perirhinal cortex (PRC) of the medial temporal lobe has been implicated in the assessment of visual object familiarity—a crucial everyday task—during both perception and memory (e.g., Murray at al., 2007). This familiarity effect is typically evidenced by reduced activation when an object becomes familiar (Henson et al., 2003). Here, we examined the PRC's role in tactile object familiarity in the absence of vision. To do so, we trained 5 blind subjects on a unique memory-guided drawing technique (Likova, 2012) which has been shown to produce spatiocognitive performance improvements and cortical reorganization in both low-level "visual" regions and high-level regions such as the inferotemporal cortex and hippocampus where perception and memory interact (Likova, 2015). The tasks (20s each) were as follows: tactile perceptual exploration of experimentally novel raised line drawings, tactile memory retrieval via drawing, and a scribble motor control. FMRI before and after a week of training on these tasks revealed a significant decrease in PRC activation from pre- to post-training (i.e., from unfamiliar to familiar) during perceptual exploration as well as memory-guided drawing, but not during the scribble control. This familiarity-based reduction is the first evidence that the PRC represents tactile object familiarity in the blind. Furthermore, the finding of this effect during both tactile perception and tactile memory provides the critical link in establishing the PRC as a structure whose representations are supramodal for both perception and memory.

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53.4098 **The mechanism of the facilitation of visual perceptual learning by reward is not the same as that by response feedback alone.** Dongho Kim[1,2](dhkim15@gmail.com), Dong-Wha Kang[2,3,4], Shigeaki Nishina[5], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Brown University (Department of Cognitive, Linguistic, and Psychological Sciences), [2]Asan Medical Center (Asan Institute for Life Sciences), [3]Asan Medical Center (Department of Neurology), [4]University of Ulsan (College of Medicine), [5]Honda Research Institute

It has been reported that visual perceptual learning (VPL) is facilitated by external reward as well as feedback as to the accuracy of subjects' response. Since both reward and feedback inform of response accuracy, it has been generally assumed that the underlying mechanism for the facilitation of VPL by these two factors was the same (e.g., reinforcement processing). However, this assumption has never been examined by a neuroscientific method. Here, we tested this assumption by comparing fMRI signals when feedback contained a high reward value with those with little or no reward value. Methods: In the high value condition, subjects (n=9) were asked not to eat or drink for five hours before a daily training session. In the low value condition, subjects (n=6) were allowed to eat or drink. FMRI measurements were conducted before, in the middle of and after training. In each trial of both the training and fMRI sessions, subjects were asked to perform a texture discrimination task. For a correct response to the target orientation, water was provided with subjects in both conditions through a tube from a water feeder. Results: First, although improvements in the task performance were observed in both conditions, the degree of improvement in the high value condition was significantly higher than in the low value condition. Second, the degree of fMRI signals in the trained region of V1 in both conditions was highly correlated with performance improvements. Third, as learning proceeded, fMRI signals in the hippocampus became increasingly higher in the high value condition, whereas those in the low value condition showed no change. Conclusions: The hippocampus is particularly involved in VPL by reward and not by feedback alone. Thus, the neural mechanism of facilitation of VPL by reward is not the same as that by feedback alone.

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53.4099 **Perceptual Learning Increases the Contrast Gain of the N1 Component** Jie Xi[1](xij@psych.ac.cn), Chang-Bing Huang[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, Beijing, China

Despite training makes perfect in most perceptual tasks, the neural and functional mechanisms of perceptual learning are still under debate. Here we used a combination of psychophysics, event-related potentials (ERPs), and quantitative modeling to explicitly link learning-induced behavioral improvements with changes in neural activities. Forteen subjects underwent ten sessions of training to identify the orientation of a peripherally presented sinewave grating. A set of psychophysics and ERP measurements at different retinal locations, contrast levels, and eyes were conducted before and after training. We found that training substantially improved visual acuity and contrast sensitivity functions, increased the amplitude, and decreased the latency of the ERP component N1 at the trained location. The learning effect was particularly pronounced around the trained condition, consistent with previous findings. Although modeling analysis revealed that training led to changes in both contrast and response gains of N1 component, only the magnitude of contrast-gain change correlated with behavioral improvements in contrast sensitivity. Moreover, the learning effects and improvements in latency at the trained location were largely retained over a three-month period.

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53.4100 **Overlearning of a visual task makes the learning rapidly hyper-stabilized to protect it from being overwritten by training on a new task –A new role of overlearning since 1885–** Kazuhisa Shibata[1](kazuhisa_shibata@brown.edu), Maro Machizawa[1], Edward Walsh[2], Ji-Won Bang[1], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Department of Cognitive, Linguistics, & Psychological Science, Brown University, [2]Department of Neuroscience, Brown University

Overlearning refers to the continued training on a stimulus/task even after the learning has plateaued. Although research on overlearning has focused on how it affects retention of learning since its discovery in 1885 by Ebbinghaus, here we report a novel role of overlearning: Extensive overlearning dramatically changes the learning status from being plastic/unstable to hyper-stable to prevent the learning from being overwritten by new and different learning. First, we examined the effect of overlearning on stability of visual perceptual learning (VPL) using an interference paradigm. Training on a detection task with one orientation was immediately followed by the second training on another orientation. After VPL by the first training became plateaued, a small (slight) or large (extensive) amount of overlearning was conducted with a different group of 12 subjects. As a result, after slight overlearning VPL by the first training was retrogradely interfered with by the second training, whereas extensive overlearning made VPL by the first training anterogradely interfere with VPL by the second training. We further examined how excitatory/inhibitory neural processing is involved in overlearning by measuring the ratio of the concentrations of excitatory (glutamate) to inhibitory (GABA) neurotransmitters (E/I ratio) in the early visual areas using magnetic resonance spectroscopy. After slight overlearning, the E/I ratio became significantly higher than before training, whereas extensive overlearning made the E/I ratio significantly lower. These results suggest the following aspects. Training first makes the learning status plastic/unstable with an increased E/I ratio in the early visual areas. However, extensive overlearning makes the status hyper-stabilized with a rapid E/I ratio decrease. Such hyper-stabilization leads to anterograde interference and prevents the first learning from being overwritten by the second learning. Hyper-stabilization is different from typical stabilization which occurs over hours of time passage and allows for VPL of both the first and second trainings.

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53.4101 **The effect of tDCS on task relevant and irrelevant perceptual learning of complex objects** Chayenne Van Meel[1](chayenne.vanmeel@ppw.kuleuven.be), Nicky Daniels[1], Hans Op de Beeck[1], Annelies Baeck[1]; [1]Research unit on Brain and Cognition, University of Leuven, Belgium

During perceptual learning the visual representations in the brain are altered, but the causal role of these changes has not yet been fully characterized. Here we investigated the effect of tDCS delivered on the lateral occipital (LO) cortex on task-relevant and task-irrelevant learning of complex objects. Participants completed three training sessions and one test session on separate days. They were trained in two tasks: one relevant to object recognition (object naming in a backward masking paradigm) and one where objects were presented in the background but not relevant for the task (orientation judgment). Visual input was equated as much as possible between the tasks: an object and an oriented red line were presented in each trial in both tasks. The only crucial difference between the tasks was the relevance of the stimuli: the object was relevant for the object naming task, while the oriented red line but not the object was relevant for the orientation judgment task. During training, half of the participants received anodal tDCS stimulation on LO. In the test session, participants were tested on their ability to name the trained objects, the irrelevant objects presented during the orientation judgment task, and a new set of objects they were not exposed to during training. Participants stimulated with anodal tDCS during training showed a larger improvement of performance for the trained objects compared to participants in the sham condition. No learning effect was found for the irrelevant objects or the new objects. To conclude, this study suggests that LO plays a causal role in relevant object learning. Mere exposure is not sufficient to train object recognition in our paradigm.

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53.4102 **EEG frequency tagging reveals a neural signature of learning holistic shape representations** Mark Vergeer[1](mark.vergeer@ppw.kuleuven.be), Naoki Kogo[1], Andrey Nikolaev[1], Nihan Alp[1], Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, University of Leuven, Belgium

Past research has shed light on the different brain areas involved in shape and object processing. Nevertheless, still relatively little is known about the neural mechanisms responsible for integrating parts into coherent wholes and about the learning mechanisms involved. In the current study, we addressed these questions using the EEG frequency tagging technique, where distinct stimulus parts of a stimulus are 'tagged' by modifying the contrast of these parts at different temporal frequencies. EEG frequency power analyses typically show clear peaks at both the tagged frequencies and their harmonics. However, additional peak responses can be observed at so-called intermodulation frequencies (e.g., f1+f2; 2*f1-f2). Evoked activity at such intermodulation frequencies is caused by nonlinear interactions between neural signals carrying the two individual frequencies. Previous findings have suggested that intermodulation components reflect the neural activity involved in the integration of local elements, for instance, in face processing (Boremanse et al., 2013). Correspondingly, the current study proposes that intermodulation components are indicative of strengthening the integration of shape parts during learning. In the 4 days prior to EEG recording, observers were trained behaviorally to discriminate highly similar novel shapes into two categories that were defined based on global, holistic properties. Different observers were trained on different families of shapes in a counterbalanced design. EEG was recorded post-training on frequency-tagged versions of the trained and untrained shape family. Results showed a stronger occipital intermodulation response for trained and untrained exemplars of the trained shape family, compared to the untrained shape family. These findings indicate that learning novel, holistic shape representations is reflected by increased intermodulation, which highlights that intermodulation strength relates to the strength of emerging holistic perceptual organizations. More generally, intermodulation responses, induced by EEG frequency tagging, provide a useful tool to investigate the neural activity underlying higher-level processes in perceptual organization.

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Perceptual Learning: Training and expertise

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

53.4103 Moderate levels of physical activity enhance short-term visual plasticity in adult humans

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We have recently shown that the adult visual cortex retains a degree of neuroplasticity higher than previously thought by demonstrating that short-term monocular deprivation unexpectedly boosts the deprived eye (measured as increased predominance in binocular rivalry) and that this form of plasticity is mediated by a decrease in GABA concentration in the visual cortex (Lunghi et al, 2011, 2015). Recent studies using animal models have shown that physical exercise promotes visual plasticity by altering the excitation/inhibition balance in the primary visual cortex. We hypothesized that physical activity could enhance visual plasticity also in humans. To test this hypothesis we measured binocular rivalry between orthogonal luminance-modulated gratings (size 2°, spatial frequency: 2 cpd, contrast: 50%) in 20 adult volunteers before and after 2 hours of monocular deprivation in two conditions: an inactive control condition in which, during the deprivation period, subjects watched a movie while sitting on a chair, and a physical activity condition in which, during the deprivation period, subjects watched a movie while intermittently cycling on a stationary bicycle. We found that in the physical activity condition the effect of deprivation on binocular rivalry was potently enhanced compared to the inactive control condition: the deprived eye predominance in binocular rivalry was higher compared to the inactive control condition for at least 120 minutes after eye-patch removal. These results demonstrate that moderate levels of physical activity enhance short-term plasticity of the adult visual cortex by boosting the homeostatic response of the visual system to transient monocular deprivation, probably by inducing a change in the primary visual cortex excitation/inhibition balance. Enhancing neuroplasticity in adult subjects is fundamental for the treatment of amblyopia, that is thought to be untreatable in adulthood and for a number of different conditions, such as recovery after brain injury and prevention of pathological brain aging.

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53.4104 Training melanoma detection in photographs using the perceptual expertise training approach

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Although a deadly form of skin cancer, melanoma is treatable if detected early. Existing approaches in melanoma detection training employ a rule-based method where lesions are assessed by their Asymmetry, Border, Color, Diameter and Evolvement in appearance (i.e., the ABCDE rule). However, the rule-based training practices in melanoma detection were not effective. In the current study, we assessed an innovative way to train melanoma detection using the principles of perceptual expertise training. All participants first reviewed the ABCDE rules pamphlet, and were then given the Melanoma Detection Test (MDT) as the pre-test where they categorized a set of skin lesion images as either "melanoma" or "benign". Participants in the perceptual expertise training group received four training sessions where they were taught to categorize melanoma and benign lesions to 95% accuracy. Participants in the control group received no training. After training, all participants were retested with the same items on the MDT. As compared to the control group, the training group showed significant improvement in melanoma detection and a shifted response criterion from liberal (i.e., bias toward categorizing a lesion as melanoma) to neutral, and both improvements maintained a week after the training. These findings indicate that perceptual expertise training is a promising approach to train melanoma detection.

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53.4105 Exploring the gaze strategies of expert object recognition by the means of eye-tracking.

Simen Hagen[1](shagen@uvic.ca), Quoc Vuong[2], Lisa Scott[3], Tim Curran[4], James Tanaka[1]; [1]Department of Psychology, University of Victoria, [2]Institute of Neuroscience, Newcastle University, [3]Department of Psychology, University of Florida, [4]Department of Psychology and Neuroscience, University of Colorado Boulder

We know that object experts (e.g., bird watchers, car aficionados, dog judges) recognize objects of expertise at more specific levels of abstraction than do novices. However, the perceptual strategies that support expert recognition have not been extensively investigated. In the current study, we used eye-tracking to examine the gaze strategies associated with expert object recognition. Expert bird-watchers and novice participants discriminated birds at the species-level (e.g., Nashville warbler, Tennessee warbler) that were shown in full-view, with a gaze-contingent window, and with a gaze-contingent mask. The gaze-contingent window allowed central-view (and blocked peripheral-view) and should therefore interfere less with a local- than a holistic-recognition strategy. In contrast, the gaze-contingent mask blocked central-view (and allowed peripheral-view) and should therefore interfere more with a local- than a holistic-recognition strategy. Analysis of the performance showed that both experts and novices were affected by the gaze-contingent mask and gaze-contingent window manipulations, albeit in different ways. Novice performance was better in the window condition, in which only central-view information was available, than in the mask condition, in which only peripheral view information was available. In contrast, expert performance was better in the mask condition than in the window condition. Thus, the performance data suggest that experts encode information over a wider spatial extent than do novices. The second set of analysis, which examined the gaze-patterns corresponding to the full-view birds, show that the gaze profiles of experts are more systematic than the gaze profiles of the novices. Collectively, these data suggest that experts have knowledge about diagnostic regions of the bird and that they can quickly analyze these regions through a more holistic strategy.

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53.4106 Training-induced attentional bias alters the appearance of both trained and untrained stimuli

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Perceptual learning can have a direct impact on the perception of task-specific stimuli, and these effects can impact information processing both with and without awareness (Di Luca et al., 2010; Haijiang et al., 2006). In addition, the exogenous capture of spatial attention has also been shown to enhance the perceived contrast of a stimulus (Carrasco et al., 2004). Given these two sets of findings, we investigated whether training subjects to endogenously attend can induce changes in stimulus appearance and whether such an effect is stimulus-specific. We show that five days of training in an orientation discrimination task can alter the perceived contrast of grating stimuli at the trained compared to untrained locations. Moreover, these training-induced changes in perceived contrast transferred to influence the perception of other stimuli that were not part of the training set. Our results suggest that learning shapes the allocation of attentional priority to different locations in the visual field, and that these interactions between learning and attention can produce changes in perception in a non-stimulus-specific manner.

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53.4107 The relation between initial thresholds, learning, and generalization in three perceptual learning paradigms

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It has been suggested recently that the extent of learning in perceptual tasks can be predicted well from the initial performance according to a Weber-like law. However, the exact relationship between initial thresholds and the amount of learning and the link between learning and generalization still remained unclear. In three perceptual learning paradigms, we tested (1) how initial thresholds influence learning, (2) how the amount of learning influences generalization, and (3) how general these relationships are across different paradigms of perceptual learning. Using a 5-day training protocol in each paradigm, separate groups of observers were trained to discriminate around two different reference values: at 73 or 30% in contrast, at 45 or 15 degrees in orientation, and at 88 or 33 dots in magnitude discrimination task. In each paradigm, initial thresholds were significantly higher at the high reference (73% contrast, 45 degrees, and 88 dots) than those at the low reference (ps< 0.05). Within conditions in each paradigm, we found strong correlations between subjects' initial threshold and their percent improvement, (rs=0.63-0.82, ps< 0.01), but their relationship did not conform the proposed Weber-like law. In contrast, across conditions in each paradigm, both the average absolute improvement and the mean percent improvement confirmed the Weber-like relationship showing no difference in percent improvement between the conditions (Bayes Factors= 2-2.3). Finally, generalization of learning was proportional to the amount of learning (linear regression slopes= 0.74-0.92, r2s= 0.45-0.83). This pattern of result suggests that (1) individual variations in perceptual learning are not related to the learning process but to other factors such as motivation, (2) regardless of individual differences and testing paradigms, the amount of perceptual learning conditioned on visual attributes is proportional to the initial thresholds following a Weber-like law, and (3) generalization is linearly proportional to the amount of learning within the task.

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53.4108 Examining the utility of visual and tactile information for fitting objects through openings

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Fitting is a complex, multi-step process involving prospective planning, decision-making, and linking several small routines into a unified action. It involves choosing the correct object, navigating it over the hole, orienting it appropriately, and finally pushing it through. Fitting tasks appear on measures of children's cognitive and motor skill development. Despite its everyday relevance and theoretical importance, little is know about which type of information aids in solving fitting problems. To address this gap we examined whether visual only or visual-tactile information is effective when children solve a novel fitting task. Two- to three-year-olds were first randomly assigned to information groups and then asked to fit familiar and unfamiliar shapes through openings. In the vision group, children looked at unfamiliar shapes and were not allowed to touch them. In the visual-tactile group children looked at and manipulated unfamiliar shapes. Children in a control group manipulated familiar shapes. During 24 test trials children were presented with a wooden board with three shape cut-outs and one shape. Children's task was to fit the shape through its corresponding cut-out. Half of the trials were with unfamiliar shapes. Findings indicate that all children correctly inserted the familiar shapes. However, the control group picked the correct opening on only 68% of unfamiliar trials. In contrast, the vision group picked the correct opening on 84% of unfamiliar trials and the visual-tactile group picked the correct opening on 98% of unfamiliar trials. The findings suggest that although prior visual information helped children successfully solve the problem tactile information had an additive effect. Additionally, error analysis revealed that memory overrode both current visual and tactile information. On 58% of error trials children picked a position or opening that was correct on the previous trial. Results are discussed in terms of children's emerging use of visual and tactile information.

Acknowledgement: Ramapo TLTR, Ramapo Foundation

53.4109 Visual and numerical representations of dynamic systems

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Most natural systems are dynamic, involving a set of relationships among measurable quantities, where mathematical models describe how the quantities evolve over time. For example, water flow in the river and the number of fish in a lake both follow fixed mathematical rules. Thus, the challenge for the visual system is to integrate multiple sources of quantities over time to represent the overall changes in the system. Here we examine a dynamic system where an inflow tube is connected to a tank where objects enter. The tank is also connected to an outflow tube where objects leave. In Experiment 1, there were two conditions. In the visual condition, participants viewed objects flowing into and out of the tank in each trial, and estimated the net change of objects in the tank. In the numerical condition, participants viewed a chart showing the inflow rate of objects, a chart showing the outflow rate, and a chart showing the number of objects in the tank. Based on the charts, they estimated the net change of objects. There were three types of trials: depletion (inflow < outflow), equilibrium (inflow = outflow), and replenishment (inflow > outflow). We found that estimation error of the net change was reliably lower in the visual condition than in the numerical condition. Estimation errors were greater in depletion and replenishment trials than in equilibrium trials. This pattern of results remained the same when participants could view only the inflow and outflow information (Experiment 2), or only the tank information (Experiment 3). The current findings suggest that visual representation is more veridical than the representation derived from only numerical information. The state of equilibrium produces a more accurate representation than the state of change. Finally, the visual system can form an efficient representation of the dynamic system based on partial information.

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53.4110 Location and direction specificity in motion direction learning associated with a single-level method of constant stimuli

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Motion direction learning transfers substantially more to a new location when trained with a staircase method (Wang et al., JoV, 2014) than with a single-level method of constant stimuli (MCS) (Ball & Sekuler, 1982). Learning also transfers to an opposite direction with a TPE (training-plus-exposure) procedure when staircases are used (Zhang & Yang, 2014), but the transfer fails with the single-level MCS (Liang et al., JoV, 2015). We suspect that training with a single-level MCS, which uses a pair of fixed motion stimuli with a single-level direction difference, may allow observers to pick up extra local cues for direction judgments. These cues may not be readily available at a new location or direction. We first replicated strong location specificity in peripheral motion direction learning with the single-level MCS using a pair of moving dot patterns (Δdir = 10°). Learning transferred little to contralateral and diagonal retinal quadrants with the transfer index (TI) = 0.26. To disturb the potential local cues, we slightly jittered the directions of the stimulus pair every presentation within a range of ±4° while keeping Δdir = 10°. The direction jitters significantly increased learning transfer (TI = 0.64). We also replicated the null transfer results with TPE training in foveal motion direction learning (Δdir = 3°) with the single-level MCS (Liang et al., 2015). Learning failed to transfer to an orthogonal direction (TI = 0.25). Again if we jittered the stimulus direction within ±2° while keeping Δdir = 3°, significantly more transfer to an orthogonal direction was enabled by TPE training (TI = 0.82). These results are consistent with the local-cue learning hypothesis regarding motion direction learning with the single-level MCS, which is responsible for part of the specificity in motion direction learning literature. They also demonstrate the importance of using appropriate psychophysical methods in training to reduce specificity in perceptual learning.

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53.4111 The complete transfer of learning between component and pattern motion: psychophysical evidence for training-induced plasticity in MT

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An important question in perceptual learning is elucidation of the neural loci of learning-induced plasticity. Here, we aimed to psychophysically disentangle contributions of V1, MT and higher decision areas to learning-included plasticity for motion. To this end, we took advantage of the well-known difference between V1 and MT responses to drifting grating (component motion) and plaid (pattern motion) stimuli. METHODS: Participants (N = 14) were split into two groups. Each group trained on a left-right motion discrimination task, but with a different stimulus. Group A

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stimulus was a vertical grating with 4 °/s horizontal motion, while Group B stimulus was a plaid composed of two obliquely moving gratings, which resulted in 4 °/s horizontal plaid motion. A battery of pre- and post-tests was used to assess the nature of learning transfer. The battery included horizontally moving gratings and plaids as well as obliquely moving gratings and plaids. We also manipulated other low-level visual features (e.g., motion direction, speed, size and contrast) as a way to test for plasticity in decision areas beyond MT. RESULTS and CONCLUSIONS: We found a bi-directional transfer of learning between component gratings and plaid stimuli as long as they moved in the same apparent directions (e.g., both moving horizontally). However, we found no transfer between stimuli with different apparent directions even if they shared some of the same components (e.g., no transfer between a horizontally moving grating and a plaid stimulus that includes a horizontally moving grating). These results are inconsistent with the plasticity in V1. We also noted a strong learning specificity to other low-level visual features (e.g., size and contrast), suggesting against plasticity in higher-level decision making areas. In sum, our results strongly support that perceptual learning of motion mainly alters neuronal functions in the sensory areas, most likely in cortical area MT.

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53.4112 **The importance of color and spatial frequency information after laboratory-trained perceptual expertise** Hillary Hadley[1](hhadley@psych.umass.edu), Erik Arnold[1], Andrea Cataldo[1], James Tanaka[2], Tim Curran[3], Lisa Scott[4]; [1]Department of Psychological and Brain Sciences, University of Massachusetts Amherst, [2]Department of Psychology, University of Victoria, [3]Department of Psychology and Neuroscience, University of Colorado Boulder, [4]Department of Psychology, University of Florida

Previous expertise training with birds (Scott et al., 2006) and cars (Scott et al., 2008) suggests that subordinate-level training improves perceptual discrimination and increases occipital-temporal event-related potentials (ERPs). Here, we examined whether manipulating color or spatial frequency information influenced discrimination or ERP components after training. Adults completed 6-10 hours of training with full color images of two sets of objects trained at either the basic or subordinate level. Before and after training, participants completed a subordinate-level sequential matching task while behavioral and ERP responses were recorded. Images were either full color, grayscale, high spatial frequency (HSF: >8 cpd), or low spatial frequency (LSF: >8 cpd) filtered. Analyses of d′ suggest that training increases accuracy following subordinate- but not basic-level training for all image manipulations. Additionally, d′ varied across manipulations, where discrimination of color was superior to grayscale and HSF-filtered images, which was superior to discrimination of LSF-filtered images. Although no training-specific ERP results were found, the P1 differed across hemispheres such that it was smaller for HSF-filtered images over the LH and for both HSF- and LSF-filtered images over the RH relative to color and grayscale images. There were also greater N170 amplitudes to LSF-filtered images relative to color, grayscale, and HSF-filtered images, and to HSF-filtered images relatives to color and grayscale images. Similarly, participants exhibited larger N250 amplitudes to LSF-filtered images relative to color, grayscale, and HSF-filtered images. The current findings are consistent with previous training results (Scott et al., 2006; 2008) and suggest that subordinate-level training increased accuracy in all conditions, despite the loss of color or spatial frequency information. Although not related to training, spatial frequency filtering selectively decreased the P1 amplitude and increased the N170 and N250 amplitudes to degraded images, which may reflect disruption of early object processing.

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53.4113 **Reward Enhances Perceptual Learning and Transfer** Pan Zhang[1](zhang2005pan@126.com), Fang Hou[2], Jie Xi[1], Meng-yuan Zhang[1], Qing He[1], Zhong-Lin Lu[2], Chang-Bing Huang[1]; [1]Key Laboratory of Behavioral Science, Institute of Psychology, Chinese Academy of Sciences, [2]Laboratory of Brain Processes (LOBES), Departments of Psychology, The Ohio State University

Thirty years of research on perceptual learning has greatly improved our understanding of the nature and locus of plasticity in the human brain by focusing on many situations in which training results in improvements that are specific to the trained stimuli and task. Here, we conducted experiments to evaluate effects of monetary reward on the rate, magnitude, and generalization of perceptual learning in a sinewave grating detection task near each observer's cutoff spatial frequency on the contrast sensitivity function (CSF). Pre- and post-training CSFs were measured in both the trained and untrained eyes. Observers were given trial-by-trial, between-block, and between-session rewards with manipulated magnitudes. We found that perceptual learning with high rewards not only enhanced the magnitude and speeded up the learning rate but also transferred more to non-trained spatial frequencies and non-trained eye, compared to no or low reward conditions (all $p< 0.05$). Such reward-induced learning effects were not simply due to general attention or arousal associated with high reward because trial-by-trial reward at the scale of seconds played a significant role --- eliminating or delivering trial-by-trial reward subliminally yielded learning rates between those in high reward and no reward learning. To investigate the mechanisms of perceptual learning in different reward conditions, we measured the CSFs in both zero and high external noise conditions. Using the perceptual template model, we found that perceptual learning in the high-reward condition significantly reduced internal noise and improved the gain of the perceptual template across all spatial frequencies, while perceptual learning without reward only improved the gain of the template. Together, our result provided the first empirical evidence that reward can significantly enhance the rate, magnitude and generalization of perceptual learning through internal noise reduction. The results suggest a Hebbian augmented by reward magnitude learning rule for perceptual learning.

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53.4114 **Learning to generalize stimulus-specific learning across contexts** Ali Hashemi[1](hashea@mcmaster.ca), Matthew Pachai[1,2], Allison Sekuler[1], Patrick Bennett[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University, [2]Brain Mind Institute, School of Life Sciences, École Polytechnique Fédérale de Lausanne

Perceptual learning (PL) in a texture identification task occurs because observers become more sensitive to diagnostic stimulus components, but the particular components that are learned vary across observers. Here, we encouraged observers to adopt a specific processing strategy by manipulating the diagnostic orientation structure of textures. Six targets were generated by applying a 0±30 deg orientation-filter to band-pass filtered white noise. Targets were embedded in non-diagnostic contexts created by filtering novel textures with a 90±30 deg orientation band. The remaining empty orientations served as potential cues for distinguishing the target and context. In a 1-of-6 identification task, observers were trained with the horizontal Target alone (hT-only) or in a vertical Context (hT+vC). Before and after training, observers were tested with hT-only and hT+vC stimuli and controls (vT-only and vT+hC). Training with hT-only produced strong stimulus- and context-specific learning; hT+vC training led to weak but stimulus-specific and context-generalizable learning. Next, we examined if context-generalization reflected a broader, stimulus-transferable learning by testing hT+vC trained observers with novel hT textures. Again, learning was minimal: almost half of the observers did not exhibit learning. For those who learned, we found no evidence of context-generalization or stimulus-transfer. Finally, to make it easier to distinguish targets and context during training, target contrast was held constant while context contrast was varied with a 1up/1down staircase. Significant learning occurred: across training blocks, observers tolerated increasingly higher levels of context contrast. Unlike previous experiments, training improved performance for both the same hT+vC and hT-only stimuli; however, training did not affect performance with novel hT or vT stimuli. Thus, learning was context-generalizable but not stimulus-transferable. In conclusion, learning to identify structure in a specific orientation is difficult when that information is embedded in non-informative orientation information, but this difficulty can be overcome by providing cues to distinguish components.

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53.4115 **Learning with reduced adaptation is eccentricity specific** Hila Harris[1](hila.harris@weizmann.ac.il), Dov Sagi[1]; [1]Department of Neurobiology/Brain Research, Weizmann Institute of Science, Rehovot, Israel

Visual learning is known to be specific to the trained retinal location. Recently, learning with reduced sensory adaptation during training was shown to transfer across equal-eccentricity locations (Harris, Gliksberg, Sagi; 2012). It was suggested that generalization arises when the cortical representation is location invariant, with sensory adaptation due to repeated stimulation contributing to failure of invariance. If so, generalization is expected to fail when locations of different eccentricities are trained and tested, since retinotopic cortical representations are scaled by the cortical magnification factor (CMF). Here we tested transfer of learning across different retinal eccentricities using reduced adaptation training. Observers trained the texture discrimination task for four days with the target positioned at 4° after which they were tested and trained at 8° eccentricity. Adaptation was reduced by interleaving dummy trials, presenting stimuli consisting of uniform textures with lines tilted 45° from the target lines (ibid.). At 4° eccentricity, thresholds improved (94±9 to 66±5ms), showing learning ($p < 0.05$). On the 5th day, thresholds at the new location (8°) increased to baseline (109±11ms, N=6obs, compared with untrained control 111±18ms, N=6obs), demonstrating specificity. Thresholds decreased at the new location (8°) during days 5-8, showing re-learning (99±17 to 76±9ms, N=3obs) which further supports specificity. Therefore, even in the absence of sensory adaptation, learning does not generalize across different eccentricities. The existence of generalization across equal-eccentricity locations but not across different eccentricities, suggests that specificity of learning is a result of inhomogeneous sensory representation. A classifier trained to one eccentricity is useless when dealing with information encoded using a different receptive-field structure, as in a different eccentricity. Local adaptation is suggested to increase local variability in the encoding stage so that distinct V1 populations encode stimuli differently. While adaptation introduces 'functional' variability to the process of learning CMF adds anatomy-based variability.

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53.4116 **Can perceptual learning alleviate the global motion direction discrimination deficit in amblyopia?** Yi Gao[1](yi.gao3@mail.mcgill.ca), Alexander Baldwin[1], Robert Hess[1]; [1]Department of Ophthalmology, McGill University

Amblyopia causes a contrast sensitivity deficit in the amblyopic eye. However there is also evidence of additional deficits affecting functions further along the processing stream, e.g. an impairment in global motion processing that is not specific to the amblyopic eye. Perceptual learning studies on normal observers have demonstrated significant improvements in global motion tasks. On this basis, we have applied these methods in an attempt to: i) improve global motion processing in amblyopic observers, and ii) determine whether the learning effects are specific to the trained eye. We tested 5 normals and 6 amblyopes on a motion direction discrimination task. Our stimuli were a field of isotropic log-Gabors with peak spatial frequency of 3 c/deg (spatially band-pass "dots"). In each trial we first presented a stimulus with a fixed reference motion direction, and then a test stimulus with its motion direction defined as an offset from that reference. The observer responded whether the second interval's direction was clockwise or anti-clockwise relative to the first. The difficulty of the task was varied by modifying the offset angle. We measured monocular baseline thresholds for each eye (day 1), and then conducted 10 days of monocular training for 40 minutes/day (days 2-11). Half of the amblyopes trained with their amblyopic eye, half with their fellow eye. After training we then made two retest measurements for each eye (days 12 and 13). Surprisingly, we do not find the expected training effect in either our normal or our amblyopic observers. Thresholds were generally lower following training, however this difference is not statistically significant. It is possible that the critical difference between our study and those that have found large training effects is the spatially broadband nature of the stimuli used in previous studies.

Tuesday Afternoon Talks

Spatial Vision: Blur, crowding and summary statistics

Tuesday, May 17, 2:30 - 4:15 pm
Talk Session, Talk Room 1
Moderator: Michael Webster

54.11, *2:30 pm* **A new law defining the relationship between perceptual bias and discrimination threshold** Xue-Xin Wei[1,3](weixxpku@gmail.com), Alan Stocker[1,2,3]; [1]Department of Psychology, [2]Department of Electrical and Systems Engineering, [3]University of Pennsylvania

Perception of a stimulus variable (e.g., the angular orientation of a line segment) can be typically characterized by two fundamental psychophysical measures: perceptual bias and discrimination threshold. It has been long believed that these two measures are independent. However, we argue that this is not the case and that they are tightly coupled instead. We propose a new perceptual law that defines the relationship between perceptual bias and discrimination threshold. The law is derived from a recently proposed theory of perception that assumes that the representation of sensory information (encoding) as well as its interpretation (decoding) are optimally adapted to the statistics of the sensory input (Wei and Stocker, Nature Neuroscience, 2015). The theory predicts that both, perceptual bias and discrimination threshold, are directly constrained by the input statistics and thus are linked. We have now formalized this link, which results in a surprisingly simple mathematical relationship between perceptual bias and discrimination threshold. The relationship allows us to predict one measure from the other (up to a scaling factor and an offset), and vice versa. We tested the proposed relationship against a wide range of published data-sets for many different sensory variables (such as for e.g., local orientation, spatial frequency, motion direction, pursuit direction, heading direction, biological motion), and found that it is well supported. Importantly, we also find the relationship to hold for measured changes in discrimination threshold and perceptual bias under varying temporal and spatial context (e.g. adaptation, perceptual learning, or surround effects such as the tilt-illusion). Based on the wide empirical support, we argue that we have derived and identified a new perceptual law, which is testament to a more holistic understanding of perception.

Acknowledgement: ONR

54.12, *2:45 pm* **Can crowded letter recognition predict word recognition?** Jean-Baptiste Bernard[1,2](jean-baptiste.bernard@univ-amu.fr), Françoise Vitu-thibault[1,2], Eric Castet[1,2]; [1]Laboratoire de Psychologie Cognitive, Marseille, France, [2]Aix-Marseille Universite

Letter recognition is the primary step preceding word recognition and reading. During reading, letter information extracted at each fixation is impaired by crowding, a phenomenon that strongly limits letter identification and correct localization. In this study, we investigated whether recognition performance of a word can be predicted by recognition performance of its letters. Four subjects ran a word recognition experiment and a letter recognition experiment. The word recognition task consisted of the recognition naming of 900 words (size: 5,7,9 letters, frequency>7 occurences/million) presented at different eccentricities (lateral eccentricity from the word center: -4,-2,0,2,4 letter slots). The letter recognition task consisted of a visual span profile (VSP) measurement, recognition of 3 adjacent random letters (1040 trigrams per subject) presented at different eccentricities (lateral eccentricity from the center of the trigram: -6 to 6 letter slot). One letter size (2° x-height) and three different durations (125,250,500 ms) were randomly chosen for each trigram/word presented in both tasks. Letter and word answers were stored. As expected, word recognition rates decreased as a function of eccentricity and fixation duration for each subject (average ranges for 5 letter words: [0.28-0.94],[0.41-1],[0.55-0.97], 7 letter words: [0.19-0.91],[0.33-0.98],[0.46-1], 9 letter words: [0.29-0.85],[0.40-0.90],[0.43-0.98] respectively for 125,250,500 ms fixation duration). An ideal-observer model of word recognition using letter identity uncertainty (VSP and confusion matrices) and position uncertainty (Gaussian functions dependent on eccentricity) from the crowded letter recognition task largely underestimated letter recognition and position errors in the word recognition task. Increasing letter identity uncertainty and position uncertainty as a function of fixation duration and number of letters strongly improved the per-subject model fit. Results suggest that identity and positional uncertainties extracted from one fixation for each letter are (1) directly modulated by fixation duration and number of constituent letters and (2) sufficient to predict word recognition performance.

Acknowledgement: Labex Brain and Language Research Institute (BLRI)

54.13, *3:00 pm* **Cortical Dynamics of Perceptual Grouping and Segmentation: Crowding** Gregory Francis[1](gfrancis@purdue.edu), Mauro Manassi[2], Michael Herzog[3]; [1]Psychological Sciences, Purdue University, [2]Department of Psychology, University of California, Berkeley, [3]Laboratory of Psychophysics, Brain Mind Institute, Ecole Polytechnique Federale de Lausanne

Previous empirical studies have demonstrated that crowding effects, where a visual target can be difficult to classify when surrounded by flanking elements on either side, are strongly altered by perceptual grouping of the target and flankers. Here, we describe a real-time neural model of perceptual grouping and segmentation that allows non-specific top-down signals to alter the representation of visual percepts. This top-down control allows an observer to generate separate representations of target and flanking elements in some visual crowding situations. Simulations show that the model properly accounts for many empirically measured grouping effects in crowding; namely a target is strongly crowded if it groups with the flankers but is hardly crowded at all if the target seems to be part of a distinct group. The model segmentation process explains why adding flanking elements can (otherwise paradoxically) reduce crowding and why seemingly tiny changes to the flankers can alter perceptual grouping and dramatically alter the effects of crowding. It also explains why target-flanker similarity produces the strongest crowding effects. These attention-like mechanisms explain how observers interact with the visual representation of a scene to enable them to solve specific perceptual tasks

Acknowledgement: The research leading to these results has received funding from the European Union Seventh Framework Programme (FP7/2007-2013) under grant agreement n° 604102 (HBP).

54.14, *3:15 pm* **Development of crowding: A new chart to measure crowding without requiring good fixation** Denis Pelli[1](denis.pelli@nyu.edu), Hormet Yiltiz[1]; [1]Psychology Dept, NYU

Evidence from the periphery, strabismic amblyopia, apperceptive agnosia, and posterior cortical atrophy show an association between the critical spacing of crowding and neural density, the number of cortical neurons per deg^2 responding to a given eye (see Strappini, et al., submitted to Cortex). Evidence for reduction in the critical spacing of crowding in development could be misleading if it's merely a result of improved fixation with age. David Regan introduced a repeated-letter acuity test, to measure acuity without requiring good fixation. We use a variant of that test here to measure acuity, and we introduce a new repeated-letter crowding test to measure crowding without requiring good fixation. Regan's repeated-letter acuity test repeats the target letter AAAAA. Our repeated-letter crowding test alternates two targets ABABABABAB and the observer is asked to report both targets. For a balanced design, we create a dual-target repeated-letter acuity test AAAAABBBBB, and ask the observer to report both targets. We also use conventional single-target tests for acuity A and crowding XAX. Center-to-center letter spacing was always 1.4 times the letter size, and we used QUEST to adjust size (or spacing) to threshold, allowing the other parameter to co-vary. Pilot data on three normally sighted students shows excellent agreement between threshold size & spacing measured with single vs. repeated targets: size 0.054±1 vs. 0.050±4 deg & spacing 0.083±6 vs. 0.081±10 deg (M±SE). Conclusions: 1. Repeating the targets does not change threshold size and spacing in normally sighted adult observers with good fixation. 2. Repeating a single letter does not produce crowding, presumably because jumbling the target and flanker features yields the same features as a target alone. 3. This chart is a promising way to measure the development of foveal crowding even in patients or children with poor fixation.

54.15, *3:30 pm* **Seeing number through the lens of texture: Summary statistics and reduced peripheral numerosity.** Benjamin Balas[1](benjamin.balas@ndsu.edu); [1]Psychology Department, North Dakota State University

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Peripheral vision is impoverished relative to foveal vision in several ways, including acuity, contrast sensitivity, and color sensitivity. Besides these factors, visual crowding also severely limits peripheral visual recognition: Items within "pooling regions" that grow larger with increasing eccentricity are subject to some form of aggregate processing that tends to reduce observers' ability to correctly identify targets. Besides failures of visual recognition, it has recently been shown that perceived numerosity in the periphery also appears to be affected by crowding. Specifically, numerosity is reduced in peripheral vision, suggesting that the integration process that combines information within pooling regions does so in a manner that systematically underestimates how many items are in an array. Presently, we examined mechanisms of visual crowding that may explain this phenomenon. We have previously demonstrated that summary-statistic representations account for many features of visual crowding and other tasks involving peripheral vision. We therefore applied a summary-statistic model of peripheral vision to object arrays to determine if numerosity was systematically reduced in "mongrel" images that reflect appearance constraints imposed by texture features. For displays of varying size (40, 60, or 80 dots) we found that numerosity was indeed reduced in mongrel images over a range of model parameter values in good agreement with prior behavioral results. We also identified parameter ranges where the model does not match behavior, placing key constraints on the tuning of the underlying model. Finally, by varying the shape and size of the elements in our arrays, we found that our model predicts that peripheral numerosity may be underestimated by varying amounts as a function of these properties, and in some cases may even be overestimated. These are novel, and to our knowledge, untested predictions regarding how number may be perceived in the visual periphery using summary statistics.

54.16, *3:45 pm* **The power of populations: How the brain represents features and summary statistics** Shaul Hochstein[1](shaulhochstein@gmail.com); [1]ELSC Safra Brain Center, Neurobiology Department, Life Sciences Institute, Hebrew University, Jerusalem

Introduction. Much recent interest has been directed at perception of summary statistics. As discussed in a variety of presentations at this and previous VSS meetings, intensive research has uncovered diverse dimensions of summary statistic perception, including simple and complex dimensions (from circle size and Gabor orientation to face emotion and attractiveness), the type of statistics acquired (mean, variance, range), and our ability to summarize elements presented simultaneously or sequentially and to divide displays into separate groups, detecting statistics of each. Methods. I now tackle a central question that remains unanswered: How does the brain compute scene summary statistics without first attaining knowledge of each scene element? One possible solution is that the brain uses implicit individual element information to compute summary statistics, which become consciously accessible first. I show that this added step is superfluous. On the contrary, direct acquisition of summary statistics is not surprising and no novel computational principle is required for summary perception. Results. A simple population code representation, as found for single element parameters, may be scaled up to compute mean values for element groups. The range of active neurons is broader, but the computation is the same for sets of elements as for a single element. Using a population code adds tremendous power, as it allows direct determination of which elements to include in the set, which elements are outliers – to be excluded and trigger pop out attention – and how to divide between simultaneously presented sets. Conclusion. Population coding provides a direct and efficient representation of set summary statistics. As suggested by Reverse Hierarchy Theory, conscious perception may begin with summary statistics, seeing many similar elements as a group, and only later focus attention to individual elements. Interestingly, a similar population code representation may underlie categorization, including both category prototype and its boundaries.

Acknowledgement: Israel Science Foundation

54.17, *4:00 pm* **Blur and sharpness discrimination and adaptation** Siddhart Srivatsav[1](sidopto@gmail.com), Michael Webster[1]; [1]Cognitive and Brain Sciences, Department of Psychology, University of Nevada, Reno

The blur discrimination function provides a standard measure of sensitivity to image blur, but is typically one-sided (extending from focused to increasingly blurred pedestals). We examined the shape of the function for stimuli that were also over-sharpened relative to the level of physical focus. Edge blur and sharpness were varied symmetrically about the focus point by varying the slope of the amplitude spectrum. Discrimination of slope changes has been examined in a number of studies, but has typically been assessed with natural images or noise. We instead examined slope discriminations for grayscale checkerboard patterns, which more closely parallel the simple edges used to assess blur discrimination. Subjects judged which of two images shown above or below a central fixation point appeared more blurred, with the threshold slope difference estimated with a 2AFC staircase. For these simple edges the discrimination function shows a minimum shifted toward slightly blurry images (i.e. steeper slopes), reminiscent to the dipper function characteristic of Gaussian-blurred edges. The lack of a corresponding dip for sharper (shallower) slopes suggests that the "norm" of image focus does not reflect a special neutral point in blur sensitivity, despite being a well-defined subjectively. In further experiments we examined how blur discrimination was affected by adaptation to blurred or sharpened edges. These showed shifts in directions consistent with the changes in perceived blur (i.e. after adapting to more blurred edges, test edges appeared sharper and there was a shift in the discrimination function toward blurrier edges). This suggests that adaptation can produce short-term changes in some aspects of blur sensitivity, in addition to the large changes it produces in the appearance of blur. Supported by EY10834

Development: Atypical

Tuesday, May 17, 2:30 - 4:15 pm
Talk Session, Talk Room 2
Moderator: Sheila Crewther

54.21, *2:30 pm* **Plasticity and functional connectivity in foveal and peripheral V1 of congenitally blind individuals** Shipra Kanjlia[1](skanjli1@jhu.edu), Connor Lane[1], Lisa Feigenson[1], Marina Bedny[1]; [1]Psychological and Brain Sciences, Johns Hopkins University

How do innate predispositions interact with experience to produce functional specialization in the human brain? We address this question by studying the function of V1 in congenitally blind individuals. We first asked whether foveal and peripheral V1 experience different patterns of plasticity in blindness. Second, we asked whether this sub-specialization of function within V1 is predicted by the functional connectivity biases of foveal as opposed to peripheral V1. Congenitally blind (n=17) and sighted adults (n=19) underwent fMRI while performing a math task and a language comprehension task. In the math task, participants judged whether the value of an unknown variable was the same across two equations (e.g. 7-2=x, 8-3=x). Equation difficulty was manipulated by using either single- or double-digit math equations (e.g. 7-2=x vs. 27-12=x) and by manipulating the algebraic complexity of math equations (e.g. 7-2=x vs. x-2=7). In the language task, participants answered yes/no questions about sentences. A subset of these blind (n=13) and sighted (n=9) adults completed a resting state scan. Peripheral and foveal V1 showed different functional profiles in congenitally blind individuals. Whereas foveal V1 responded more to math equations and was sensitive to equation difficulty, peripheral V1 responded more to sentences and was sensitive to syntactic complexity. This functional dissociation was related to resting state correlations. Whereas foveal V1 was correlated with math-responsive regions in dorsal prefrontal cortex, peripheral V1 was correlated with language responsive regions in inferior frontal cortex. Crucially, these biases in resting state correlations were observed even in the sighted group, in whom V1 was not sensitive to either the language or number tasks. These results suggest that visual cortex plasticity in blindness builds upon pre-existing connectivity biases. That is, the consequences of these connectivity biases on cortical function depend on visual experience.

Acknowledgement: National Science Foundation Graduate Research Fellowship Science of Learning Institute

54.22, *2:45 pm* **A possible account of impairments in configural face processing following early visual deprivation** Sharon Gilad-Gutnick[1](sharongu@mit.edu), Evan Ehrenberg[1], Sidney Diamond[1], Richard Held[1], Amy Kalia[1], Tapan Gandhi[2], Kleovoulos Tsourides[3], Margaret Kjelgaard[4], Pawan Sinha[1]; [1]Brain and Cognitive Science, Massachusetts Institute of Technology, [2]Department of Electrical Engineering, IIT, Delhi, [3]Computation & Neural Systems, Caltech, [4]Communication Sciences and Disorders, MGH-IHP

Studies of individuals who were treated for congenital cataracts early in life have yielded an intriguing finding: when tested on face individuation tasks several years after treatment, they exhibit impairments in configural processing relative to those who had normal visual development. The genesis of this impairment is unclear, but explanations have tended to focus on the idea of a 'critical period' for normal development of face processing. Deprived of patterned visual inputs during this period, the brain is believed to be permanently compromised in its ability to analyze facial information. While plausible, this account suffers from two weaknesses. First, it ascribes a special status to faces as a visual class in order to explain why only face processing, but not general object processing are compromised due to early visual deprivation. Second, the account leaves unspecified why within the domain of face processing the impairment is so narrowly circumscribed, with only configural processing being adversely affected. Here we propose a parsimonious alternative hypothesis that sidesteps these weaknesses. Building upon the observation that the post-operative acuity that this group of individuals start out with is higher than that available to the typically developing visual system, we have conducted computational simulations to probe how high-resolution information may impact the learning of facial representations. These experiments reveal a detrimental effect of high initial acuity on configural encoding. This leads us to suggest that the face processing deficits reported in individuals who had suffered early visual deprivation may be due, at least in part, to having access to fine image structure beyond what normal development allows. The hypothesis has potential implications for understanding prosopagnosia, the design of therapeutic interventions, and cautions to be followed in the post-operative care of children treated for congenital blindness.

54.23, *3:00 pm* **Early Visual Experience is Important for Audiovisual but not for Visuotactile Integration** Terri Lewis[1,2](lewistl@mcmaster.ca), Yi-Chuan Chen[3], David Shore[1], Brendan Stanley[1], Daphne Maurer[1,2]; [1]Dept of Psychology, Neuroscience & Behaviour, McMaster University, Hamilton, Canada, [2]Dept of Ophthalmology and Vision Sciences, The Hospital for Sick Children, Toronto, Canada, [3]Dept of Experimental Psychology, University of Oxford, Oxford, United Kingdom

Simultaneity is one of the basic rules of multisensory integration and the basis for learning associations between visual and auditory (or tactile) stimuli. Here, we compared the audiovisual and visuotactile simultaneity windows in normal development and in patients who had been deprived of patterned vision during the first 0.3-28.3 months of life (M=4.59 months) by reversible dense cataracts in one or both eyes (n= 13/grp for audiovisual and 12/grp for visuotactile). Participants made judgments about the simultaneity of a flash and a beep (or a tap) that were presented with various stimulus onset asynchronies (SOAs). During normal development, the simultaneity windows became progressively narrower for both visual-leading and auditory-leading (or tactile-leading) SOAs, maturing 2 years earlier for audiovisual (at age 9) than for visuotactile (at age 11) simultaneity. Patients showed reduced and poorly calibrated interactions between vision and hearing. For unilateral patients, the simultaneity window was wider than normal at both visual- and auditory-leading SOAs ($ps < .05$), a pattern similar to that of younger typically-developing children. For bilateral patients, the simultaneity window was again wider than normal ($p < .05$) but mainly for the visual-leading SOAs, an asymmetry not seen in normal development. The window of visuotactile simultaneity, in contrast, was entirely normal after both unilateral and bilateral deprivation ($ps > .27$). Thus, abnormal visual experience, lasting only a few months after birth, has permanent long-term consequences for audiovisual interactions but not visuotactile interactions. The greater variability (thus poorer reliability) in auditory arrival times compared to tactile arrival times may explain the difference. Alternatively, the direct feedback about the source of the tactile stimulus in the visuotactile system, unlike the case of auditory localization in the audiovisual system, may allow the system to be calibrated even after early visual deprivation.

Acknowledgement: James S. McDonnell Foundation and Natural Sciences and Engineering Research Council of Canada

54.24, *3:15 pm* **The developing ventral visual pathway in a young patient following right posterior hemispherectomy** Tina Liu[1](tinaliu@cmu.edu), Adrian Nestor[2], Mark Vida[1], John Pyles[1], Christina Patterson[3], Marlene Behrmann[1]; [1]Department of Psychology and Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Department of Psychology, University of Toronto Scarborough, [3]Children's Hospital of Pittsburgh of UPMC

Understanding the extent and nature of cortical plasticity in human vision remains a key challenge for neuroscience. Given the bilateral cortical organization of both early and higher-order visual cortex, the visual system post-hemispherectomy/lobectomy offers a unique opportunity to explore cortical reorganization. Here, we report a longitudinal case study of a young male patient who underwent surgical removal of the entire right occipital and posterior temporal lobe at age 6.9 years. In order to 1) examine how extensive removal of the right ventral visual pathway alters the dynamics of the visual processing in the remaining cortex, and 2) characterize reorganization in category-selective regions over time, we used the same fMRI scanning protocol three times at 6 month intervals (starting 1 year post-surgery) to map category-selective activations (face, scene, object, and word). Whereas selectivity for scenes and objects remained stable across all three sessions, changes were most evident in the face- and word-selective regions. Although the developing face network largely involved a remapping to the left hemisphere (which is not typically specialized for face processing), it is consistent with evidence from the behavioral investigation that revealed age-appropriate face recognition abilities in this child. A substantial increase in word-selective activation was also observed in the left hemisphere with a significant lateral shift in both the peak and centroid of activation over time, suggesting competition between face- and word-processing when both are confined to a single hemisphere. Last, but not least, these dynamic changes in higher-order visual cortex occurred despite the limited plasticity in the earlier parts of visual cortex, as reflected by retinotopic mapping and behavioral visual perimetry testing. Overall, these findings reveal that, following extensive removal of visual cortex, there is limited plasticity in early visual cortex but developing and reorganized selectivity for several visual categories, accompanied by good visual performance.

Acknowledgement: Grant support: This research was supported by a grant from the National Institutes of Health (EY023067) to MB.

54.25, *3:30 pm* **Altered balance between excitation and suppression in visual cortex of amblyopic macaques** Luke Hallum[1](hallum@cns.nyu.edu), Christopher Shooner[1], Romesh Kumbhani[1], Najib Majaj[1], J. Anthony Movshon[1], Lynne Kiorpes[1]; [1]Center for Neural Science, New York University

Amblyopia is a developmental disorder leading to form vision deficits in the affected eye and interocular perceptual suppression. Monocular testing has revealed neuronal response patterns that can partly account for the form deficits, but few have studied amblyopic cortical responses under binocular viewing conditions. We wondered whether dichoptic testing could improve response field (RF) characterization and furnish a more complete account of the cortical deficit. We recorded from 96-electrode "Utah" arrays straddling the V1/V2 border (eccentricities: 0.5 to 7 degrees) in each hemisphere of seven anesthetized macaques: six behaviorally assessed amblyopes and one visually-normal control. We presented large, contrast-modulated gratings to both eyes simultaneously. Grating parameters were chosen to vigorously drive overall responses. Data revealed dichoptic suppression: increasing contrast in the amblyopic eye (AE) decreased responses at binocular cortical sites. We modeled RFs using a difference of Gaussian envelopes (Hallum & Movshon, Vision Research, 2014), estimating the magnitudes of central excitation and surrounding suppression. To quantify the excitation/suppression balance, we used indices of the form $V = (A-B)/(A+B)$. Within eye, A and B were model-based estimates of the magnitudes of excitation and suppression, respectively. For fellow (FE) and control eyes, excitation dominated suppression, while for AEs, suppression dominated excitation. V was associated with depth of amblyopia. Between eyes, A and B were model-based estimates of either (1) FE excitation and AE excitation, respectively, or (2) FE suppression and AE suppression, respectively. For the control macaque, excitation and suppression were balanced. Between the eyes of amblyopes, FE excitation dominated AE excitation; V tended toward higher values in severe amblyopia. Suppression appeared unaffected by amblyopia. These response patterns likely reflect the mechanisms mediating interocular perceptual suppression.

Acknowledgement: NIH EY05864, EY22428

54.26, *3:45 pm* **Specific Vulnerability of Components of Visual Attention and Global Motion Following Perinatal Brain Injury** Janette Atkinson[1](j.atkinson@ucl.ac.uk), Oliver Braddick[2], Christine Monague-Johnson[3], Morag Andrew[3], Bonny Baker[3], Jeremy Parr[4], Peter Sullivan[3]; [1]Div Psychology & Language Sciences, University College London, [2]Experimental Psychology, University of Oxford, [3]Paediatrics, University of Oxford, [4]Institute of Neuroscience, Newcastle University

Perinatal brain injury (PBI) and very premature birth are associated with a range of visual and visuo-cognitive deficits in later childhood, many related to dorsal stream function. Previously we reported deficits in cortical infant attention (FSP-fixation shift paradigm) and VEP timing in a cohort of 55 children with PBI participating in the Dolphin dietary trial [Braddick et al, VSS 2014]. Here we (a) compare global form and motion sensitivity with visual subtests from the Early Childhood Attention Battery (ECAB; Breckenridge et al (2013a), Brit J Dev Psy 31,271: selective/ sustained/ executive control) in PBI children between 4-6 years of age and (b) examine whether infant attention deficits using FSP predict specific ECAB deficits. 28 children (mean age 4:11) showed) deficits in attention and global motion sensitivity which varied across children, but was generally substantially greater than expected, given modest cognitive impair-

 See page 3 for Abstract Numbering System

ment found on the Kaufman ABC-II battery (mean standard score 9.2) Standard scores, scaled relative to mental age (expected value=10), were particularly low on visual search, sustained attention, and counterpointing (executive control) (mean = 5.9, 5.5, and 6.5 respectively) and lower for global motion (8.2) than for global form (9.3). Age based standard scores showed highly significant correlations between global motion sensitivity and the ECAB search and flanker tests. Infant attention deficits, identified with FSP, correlated significantly with scores on the ECAB flanker test. We conclude that performance on attention and global motion are correlated in PBI and substantially impaired over and above general cognitive disability. The PBI profile of attentional impairment differs from that previously found in genetic neurodevelopmental disorders (Breckenridge et al, 2013b, Brit J Dev Psy 31,259) in terms of marked sustained attention deficits. However, we do not know yet whether there are causal relationships between different impairments comprising "dorsal stream vulnerability".

Acknowledgement: Leverhulme Trust, Castang Foundation, Nutricia

54.27, *4:00 pm* **Evidence for elevated internal noise in Autism Spectrum Disorder** Woon Ju Park[1,2](wjpark@mail.bcs.rochester.edu), Kimberly Schauder[3], Loisa Bennetto[2,3], Duje Tadin[1,2,4]; [1]Center for Visual Science, University of Rochester, [2]Department of Brain and Cognitive Sciences, University of Rochester, [3]Department of Clinical and Social Sciences in Psychology, University of Rochester, [4]Department of Opthalmology, University of Rochester School of Medicine

Atypical sensory processing in Autism Spectrum Disorder (ASD) is widely acknowledged, but the underlying mechanisms are not well understood. Sensory noise plays a critical role in perceptual processing efficiency, but its influence in sensory symptoms in ASD is not yet clear. Recent evidence showed increased inter-trial variability in neural responses to sensory stimuli in ASD (e.g., Dinstein et al., 2012), suggesting that sensory responses might be atypically noisy in ASD. Here, we investigated the link between internal noise and visual perception in ASD. Using an equivalent noise paradigm, we tested the hypothesis that increased internal noise in ASD will lead to impaired visual sensitivity. METHODS: Participants were 21 children with ASD (ages 9-16) and 20 matched typically developing (TD) controls. They performed an orientation discrimination task on foveally presented gratings (1.5° radius; orientation was either -45° or 45° from the vertical). Contrast thresholds were measured at 8 levels of external noise (0-21%). Stimulus presentation was controlled using the FAST toolbox (Vul et al., 2008) and results were fitted with Bayesian estimation. This yielded reliable estimates of the entire threshold-versus-noise function in only 480 trials per individual. The perceptual template model (Lu & Dosher, 2008) was used to evaluate the effect of internal noise. RESULTS: Relative to TD controls, children with ASD showed higher contrast thresholds at lower external noise levels. Similar thresholds were observed at high external noise levels. The model analysis revealed that the data are best explained by increased internal additive noise in ASD compared to TD. CONCLUSIONS: We show evidence that high internal noise in ASD may be an important factor limiting visual orientation processing of individuals with ASD. This finding further suggests that increased variability in sensory processing may be, at least in part, underlying the presence of atypical sensory symptoms in ASD.

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Motion and Temporal Processing: Models and mechanisms

Tuesday, May 17, 5:15 - 7:15 pm
Talk Session, Talk Room 1
Moderator: Kaoru Amano

55.11, *5:15 pm* **Temporal modulations enhance spatial resolution for dynamic stimuli** Jonathan Patrick[1](lpxjap@nottingham.ac.uk), Neil Roach[1], Paul McGraw[1]; [1]School of Psychology, The University of Nottingham

The loss of central vision experienced by patients with age-related macular degeneration (ARMD) means they must rely on peripheral vision, which is limited in its spatial resolution capacity. Here we investigate stimulus manipulations intended to improve resolution for dynamic targets. Resolution thresholds were measured using a monocular four-alternative orientation discrimination task with Landolt rings presented at 10deg eccentricity. Two types of image motion were investigated along with two different forms of temporal manipulation. Ocular motion was simulated by jittering target location using previously recorded fixational eye movement data, amplified by a variable gain factor (0 to 8). Object motion was generated by translating a target along an isoeccentric path at a constant speed (0-20deg/s). In one stimulus manipulation, the sequence was temporally subsampled by displaying the target on a total of five evenly spaced video frames in the 25-frame sequence. In the other manipulation, the contrast polarity of the stimulus was reversed from white to black after every five video frames. With simulated ocular motion, we found that resolution thresholds were consistently improved by contrast polarity reversal but impaired by temporal subsampling. Resolution thresholds with object motion were again improved at all speeds by reversing contrast polarity, while temporal subsampling was found to improve resolution thresholds at high speeds but degrade performance for low speeds. These results suggest that contrast polarity reversal and temporal subsampling produce differential effects on spatial resolution under different types of retinal motion. Applying contrast polarity reversal to peripheral scenes may have the potential to improve visual performance for those with a loss of foveal visual function.

Acknowledgement: Fight for Sight

55.12, *5:30 pm* **Illusory jitter perceived at the frequency of intrinsic alpha oscillation** Sorato Minami[1,2](minami@fbs.osaka-u.ac.jp), Kaoru Amano[1,2]; [1]Center for Information and Neural Networks, National Institute of Information and Communications Technology, [2]Graduate School of Frontier Biosciences, Osaka University

Introduction: Recent studies have demonstrated the possible involvement of alpha oscillation (8–13 Hz) in visual processing (Jensen et al., 2012), but its functional role remains unknown. Here we tested the hypothesis that interaction between visual areas is mediated by the intrinsic alpha rhythm. We utilized an illusory jitter perception called motion-induced spatial conflict (Arnold and Johnston, 2003) which is ideal to highlight the interaction between visual areas. In this illusion, a moving isoluminant border is placed in close proximity to moving luminance-defined borders. As the isoluminant borders are perceived to move slower than the luminance-defined borders, dissociation between motion-based and object-based position representations is created. Methods: In the first experiment, the perceived jitter frequency of individual participants was compared with their peak alpha frequency (PAF) during resting state. In the second experiment, we measured the change in PAF within individual participants, correlated with the change in perceived jitter frequency. In the third experiment, we performed source localization on the MEG data during the perception of illusory jitter to directly test the hypothesis. Results and Discussion: In the first experiment, we found a significant correlation between perceived jitter frequency and PAF during resting state. In the second experiment, PAF in the perceptually slower jitter trials was significantly lower than that in faster jitter trials. These results suggest that the perceived frequency of illusory jitter reflects not only the inter-subject but also intra-subject variation of PAF. In the third experiment, alpha power in IPL as well as the coherence between IPL and IT at the alpha frequency was found to significantly increase during perception of illusory jitter. These results support the idea that the dissociation between motion-based delayed position representation in the dorsal stream and the object-based accurate position representation are resolved at the intrinsic alpha frequency.

55.13, *5:45 pm* **Something out of nothing: The role of alpha-frequency reverberation in the triple-flash illusion** Rasa Gulbinaite[1,2](rasa.gulbinaite@gmail.com), Barkin Ilhan[3], Rufin VanRullen[1,2]; [1]Universite Paul Sabatier, Toulouse, France, [2]Centre de Recherche Cerveau et Cognition, CNRS UMR 5549, Toulouse, France, [3]Meram Medical Faculty, Konya N.E. University, Konya, Turkey

Two successive flashes can sometimes be perceived as three, and predominantly when the delay between flashes is ~100ms [Bowen, 1989]. This "triple-flash" illusion was proposed to result from the hypothetical superposition of two oscillatory impulse response functions (IRF), one for each stimulus flash. When the delay between flashes matches the period of the oscillation, the superposition enhances a later part of the oscillation that is normally damped; when this enhancement crosses perceptual threshold, a third flash is erroneously perceived. However, so far no electrophysiological evidence supports this theoretical account of the illusion. In Experiment 1, we systematically varied the inter-flash interval (stimulus onset asynchrony, SOA) and validated Bowen's theory: The subject-specific optimal SOA for illusory perception was strongly correlated with the period of that person's parietal "perceptual echo" – an oscillatory IRF measured in a separate EEG experiment [as described in VanRullen & Macdonald, 2012]. Although this finding lends support to Bowen's notion that the illusion reflects a superposition of two oscillatory responses, it does not

explain trial-to-trial variability: At the subject-specific optimal SOA, the third flash is only perceived on average half of the time (45%). In Experiment 2, by presenting two flashes at a fixed SOA while recording EEG, we contrasted brain activity for physically identical trials on which the third-flash was either reported, or not. The findings revealed that: (1) Across subjects, the probability of third-flash perception was correlated with subject-specific alpha peak frequency at parietal but not occipital sources (measured during the baseline, prior to the first flash); (2) Significantly stronger alpha-band (7-11 Hz) inter-trial phase coherence at parietal sites 210-250ms after the first flash was related to the perception of the third illusory flash. Overall, oscillatory reverberations in the brain can create something out of nothing – a third flash where there are only two.

Acknowledgement: ERC Consolidator Grant P-CYCLES number 614244

55.14, *6:00 pm* **Duration adaptation is position-invariant** Jim Maarseveen[1](J.Maarseveen@uu.nl), Hinze Hogendoorn[1,2], Frans Verstraten[1,2], Chris Paffen[1]; [1]Utrecht University, Helmholtz Institute, Department of Experimental Psychology, The Netherlands, [2]University of Sydney, Faculty of Science, School of Psychology, Sydney, NSW 2006, Australia

Adapting to the duration of a visual stimulus causes the perceived duration of a subsequently presented stimulus with a slightly different duration to be skewed away from the adapted duration. This pattern of repulsion following adaptation is similar to that observed for other visual properties, such as orientation, and is considered as evidence for duration-selective channels (Heron, et al. 2012). Here, we investigated the spatial selectivity of these duration channels by varying the distance between adaptation and test stimulus. Observers were presented with a 100 repetitions of a Gaussian blob (σ = 0.75°) located 8° above a central fixation cross, lasting either 160 or 640 ms. Following adaptation, participants completed a duration comparison task with each trial starting with four top-ups followed by the presentation of an auditory reference (320 ms) and a visual test stimulus. The duration of the visual test stimulus was varied using a staircase procedure to obtain the point of subjective equality. To investigate the spatial extent of the adaptation effect, the distance between adaptation and test stimuli was varied between 0° to 15° with the stimuli always presented at an eccentricity of 8°. Our results show a clear duration adaptation effect: the test stimulus was perceived to have a longer duration following adaptation to a shorter duration, and a shorter duration following adaptation to a longer duration. Importantly, this adaptation effect occurred at all measured distances, and there was no evidence for a decrease in the strength of adaptation at larger distances. We conclude that duration adaptation is position-invariant, transferring to locations separated by more than 10° from the location of the adaptation stimulus. Given the spatial extent of the adaptation effect, it seems unlikely that the proposed duration channels are represented in lower level retinotopically organized visual areas, instead suggesting a later locus.

55.15, *6:15 pm* **Speed-Size Illusion Explained by Empirical Ranking Theory** Zixin Yong[1](y.z@u.duke.nus.edu), Po-Jang Hsieh[1]; [1]Duke-NUS Medical School

Large objects are perceived to move slower than smaller ones with the same physical speed. This puzzling perceptual illusion, called the speed-size illusion, is observed in daily life and deemed to be one of the causes of railway crossing collisions. Despite its prevalence in our sensory experiences, no well-grounded explanation has been given. Here we show that the speed-size illusion can be explained by objects' speed occurrence frequency, which is intrinsically embedded in the natural environment statistics. We first conducted experiments to quantify this illusion by determining the subjective equal speeds of moving spheres with various sizes. Then we obtained objects' speed distribution statistics by simulating a virtual environment, where moving objects' size and speed projected onto an image plane. The simulation served as a proxy of retinal image formation process in the natural environment, whose object motions are ambiguous and computationally challenging to track. The simulation showed that for any given speed, larger object possess a lower percentile rank in its speed accumulation probability curve, which accounts for its lower perceived speed. Furthermore, the results of our psychophysical experiments can be predicted by the simulation to a good extent. It thus implies that the speed-size illusion is a result of past experiences accumulated in the environment, and perceptual qualities are empirically evolved according to the frequency of occurrence of the corresponding stimuli. Our study corroborates the Empirical Ranking Theory1 of visual perception. 1. Purves, Dale, et al. "How biological vision succeeds in the physical world." Proceedings of the National Academy of Sciences 111.13 (2014): 4750-4755.

55.16, *6:30 pm* **Speed channel interactions in naturalistic motion stimuli** Nikos Gekas[1](nikos.gekas@outlook.com), Andrew Meso[2], Guillaume Masson[2], Pascal Mamassian[1]; [1]Laboratoire des Systèmes Perceptifs, CNRS UMR8248, Département d'Études Cognitives, École Normale Supérieure, Paris, France, [2]Institut de Neurosciences de la Timone, UMR7289, CNRS/Aix-Marseille Université, Marseille, France

Human observers are very sensitive to speeds of moving stimuli. However little is known about how such sensitivity arises independently upon the spatiotemporal properties of the stimulus. Here, we investigate the interactions between spatiotemporal frequency channels, and, in particular, how different speeds are integrated as a function of the spatiotemporal frequency content. We used naturalistic random textures ("Motion Clouds" - MCs, Simoncini et al., 2012, Nat. Neurosci. 15(11):1596-1603) to control the exact range of spatiotemporal frequencies of the stimulus. In a preliminary experiment, we combined two MCs of diverging mean spatial or temporal frequencies, and calculated the threshold up to which human observers were able to discriminate between one complex stimulus versus two interleaving stimuli. Then, we generated stimuli composed of three component MCs, which moved at one of three specific speeds and had different mean spatial or temporal frequencies. Six distinct components were arranged in four combinations in spatiotemporal space. Thus, all complex stimuli moved at the same average speed but each activated distinct channels. We measured the perceived speed of the multi-component stimuli in a psychophysical 2AFC task in which participants were asked to compare the speed of the MC stimulus with that of a random dot kinematogram. Our results suggest that systematic manipulation of speed channel interactions can affect the perceived absolute speed of the stimulus as well as the sensitivity to the perceived speed. We found that neighboring channels in spatiotemporal space interact with each other in specific directions. The results appear to partially agree with predictions made by a computational model of motion perception (Perrone, 2012, JoV 12(8):1), however they also hint at more complex, but yet unidentified rules in the weighting of different channels in the decoding of speed information.

55.17, *6:45 pm* **Representations along the path of apparent motion in visual cortex** Gennady Erlikhman[1](gennaer@gmail.com), Gideon Caplovitz[1]; [1]Department of Psychology, University of Nevada, Reno

During apparent motion (AM), an object appears to move smoothly between several locations despite being physically present only intermittently. It has been shown that AM can modulate neural activity within regions of motion-sensitive cortex (hMT+) and primary visual cortex (V1) that represent non-stimulated regions of space along the AM path. However, it is not clear (1) where corresponding neural modulations originate: in early visual cortex due to feedback from higher visual areas or through long-range horizontal connections within early areas, and (2) what information is being represented within these regions: whether it is shape or identity information about the object itself or non-object-specific information such as position, velocity or even the focus of attention. We applied fMRI in human subjects to examine the representation of information within visual cortex along the AM path. Observers viewed AM displays in which either a circle or a star traversed back and forth between the upper-right and lower-left visual fields. Importantly, these stimuli were unlikely to trigger long-range, orientation-specific, horizontal connections within early visual cortex. In a partial replication of previous findings, we show that when a subtle occlusion cue is present, there is an increase in activity corresponding to the AM path in early visual cortex (V1, V2, and V3). However, this activity does not encode enough information to dissociate circles from stars. In contrast, patterns of activity along the AM path in higher-order topographic regions and in LOC and hMT+ are able to dissociate circles from stars even when the occlusion cue is absent. Our results suggest that object-specific information along the AM path is represented within relatively high levels of visual cortex and not the earliest stages of cortical processing. Moreover, when occlusion cues are present, non-identity-specific positional information likely arising due to feedback is represented within early visual cortex.

Acknowledgement: NIH/NIGMS 1P20GM103650-01A1 and NIH/NEI 1R15 EY022775-01

55.18, *7:00 pm* **Training alters the causal contribution of area MT to visual motion perception** Liu Liu[1](liu.liu2@mail.mcgill.ca), Christopher Pack[1]; [1]Department of Neurology & Neurosurgery, Montreal Neurological Institute, McGill University

Visual stimuli elicit neural activation in a large number of distinct cortical areas. In principle, visual perception could arise from a distributed process that combines information across these areas, or it could rely exclusively on the areas that are most specialized for each stimulus. We have examined these possibilities, using a motion discrimination task and reversible inactivation of the middle temporal (MT) area of the visual cortex. Area MT is highly specialized for processing visual motion. Monkeys were trained to report the direction of motion of a moving grating, which has been shown to be represented in many different visual cortical areas. Following this training, reversible inactivation of MT, using muscimol injections, had surprisingly little effect on behavioral performance (22% increase in psychophysical thresholds). This suggests that the brain uses a distributed representation to make perceptual decisions. The same monkeys were then trained to report the motion direction of random dots embedded in noise. This stimulus elicits far stronger direction selectivity in MT than elsewhere, suggesting that it is a specialized probe of MT; as in previous studies, we found that MT inactivation devastated behavioral performance for this stimulus. Surprisingly, following training on the dots task, we found that muscimol injections had a much more powerful effect on the perception of motion for gratings as well (500% increase in psychophysical threshold). This suggests that the readout of sensory information depends strongly on perceptual experience, and that specialized training on one stimulus can have detrimental effects on the perception of other stimuli.

Acknowledgement: CIHR MOP-115178 and CGSD-121719

Attention: Reward, emotion, motivation

Tuesday, May 17, 5:15 - 7:15 pm
Talk Session, Talk Room 2
Moderator: Andrew Leber

55.21, *5:15 pm* **Relating value-driven attentional capture to striatal dopamine: A positron emission tomography study** Brian Anderson[1](bander33@jhu.edu), Hiroto Kuwabara[2], Dean Wong[2,3,4], Emily Gean[2], Arman Rahmim[2], James Brašić[2], Noble George[2], Boris Frolov[2], Susan Courtney[2,3,5], Steven Yantis[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University, [2]Section of High Resolution Brain PET, Division of Nuclear Medicine, Russell H. Morgan Department of Radiology and Radiological Science, Johns Hopkins University School of Medicine, [3]Solomon H. Snyder Department of Neuroscience, Johns Hopkins University School of Medicine, [4]Department of Psychiatry and Behavioral Sciences, Johns Hopkins University School of Medicine, [5]F. M. Kirby Research Center, Kennedy Krieger Institute

Reward learning gives rise to strong attentional biases. Stimuli previously associated with reward automatically capture visual attention regardless of intention. Nonspecific measures of brain activity have implicated the striatum in value-driven attention. However, the neurochemical mechanisms underlying the attentional priority of learned reward cues remain unexplored, largely due to limitations inherent to the neuroimaging techniques commonly used in the field of human cognitive neuroscience. Here, we investigated the contribution of dopamine to value-driven attention using positron emission tomography (PET) with [11C]raclopride. Participants first completed a training phase in which color-defined targets were associated with a monetary reward when correctly reported, and then completed an unrewarded test phase in which these same color stimuli served as task-irrelevant distractors during visual search for a shape-defined target. Value-driven attentional capture was measured as the slowing of response time on high-value distractor trials as in prior studies. We show that the magnitude of value-driven attentional capture is correlated across individuals with the magnitude of dopamine release linked to distractor processing within the right caudate and posterior putamen. Furthermore, the ability to suppress value-driven attentional capture was associated with the suppression of striatal dopamine in these same regions. Our findings provide direct evidence linking dopamine signaling within the dorsal striatum to the involuntary orienting of attention, and specifically to the attention-grabbing quality of learned reward cues. These findings also shed light on the neurochemical basis of individual susceptibility to value-driven attentional capture, and, more broadly, highlight the value and feasibility of using PET to relate changes in the release of a neurotransmitter to attentional and learning processes in humans.

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55.22, *5:30 pm* **Arousal state enhances contrast sensitivity under conditions of exogenous attention** Rosanne Rademaker[1,2](rosanne.rademaker@maastrichtuniversity.nl), Sam Ling[3,4,5], Alexander Sack[1]; [1]Department of Cognitive Neuroscience, Maastricht University., [2]Department of Psychology, University of California San Diego., [3]Department of Psychological and Brain Sciences, Boston University., [4]Center for Computational Neuroscience and Neural Technology, Boston University, [5]Donders Institute for Brain Cognition and Behavior, Radboud University.

While physiological arousal is assumed to heighten the senses, little is actually known regarding how arousal states influence basic perceptual processing. Arousal states could prompt a wholesale modulation of the entire sensorial environment, or alternatively act primarily on behaviorally relevant information. Here we investigated if and how arousal might influence basic visual processing by assessing contrast sensitivity under physiological stress, induced by exposure to ice water (Cold Pressor Test). Specifically, we aimed to distinguish between mechanisms of attention and arousal: Does arousal mimic the effects of visual attention on contrast sensitivity, or do attention and arousal interact? We estimated contrast psychometric functions for thirty participants, who discriminated the orientation of peripherally presented gratings at 8 different levels of contrast. Exogenous attention was manipulated using a transient cue that briefly appeared either at fixation (neutral cue) or adjacent to an upcoming grating location (attended condition). Following the offset of the exogenous cue, participants performed a 2AFC fine orientation discrimination task on a grating that could appear in one of four locations (4° eccentricity). Critically, participants performed the tasks under two conditions: Once while their foot was submerged in comfortably warm water (~36º C), and a second time when the water was near freezing (~3º C). Consistent with prior work, psychometric functions revealed shifts towards higher sensitivity under the attended condition. However, contrast sensitivity was unaffected by water temperature in the unattended condition, demonstrating that arousal itself did not boost visual sensitivity. Interestingly, in the attended condition cold water increased visual sensitivity beyond the already observed increase with warm water, indicating that arousal can amplify the effects of attention, further increasing visual sensitivity. Taken together, these results suggest that arousal acts to prioritize the processing of behaviorally relevant visual information by innervating and acting on the exogenous attentional system.

55.23, *5:45 pm* **Real World Goals Are Fickle and Volatile: Consuming High Fat Foods Reduces Distraction from Entirely Irrelevant High-Fat Foods** Corbin Cunningham[1](cunningham@jhu.edu), Howard Egeth[1]; [1]Department of Psychological & Brain Sciences, Johns Hopkins University

Due to the limited processing capacity of the human visual system, it is critical to selectively respond to stimuli that are the most relevant to our current goals. While much of the research on goal-driven attentional capture investigates goals developed through artificial training (e.g. red stimuli are worth $1.00), it has failed to investigate whether naturally occurring goal states also influence attentional deployment. In the present study, we used images of high-fat foods as a case study. We hypothesized that since high-fat foods are desired by most individuals, we should see a larger amount of distraction for these images compared to other non-food objects (e.g. a bicycle). Utilizing a similar task to Forster & Lavie (2011), observers were asked to make continuous sequential forced-choice responses to each of 4 symbols in the center of the screen (e.g., is it a letter or number?). This task provided a unique experimental setup that allowed for the brief onset (125 msecs) of distractor images to be entirely irrelevant. In Experiment 1, we presented observers with three kinds of distractor images: high-fat foods, low-fat foods, and non-food objects. Results revealed that observers were significantly more distracted by high-fat foods, compared to non-food objects and even low-fat foods, suggesting observers rapidly assessed the nutritional value of the distractor images. In Experiment 2, we investigated the lability of these naturally occurring goal states by having observers consume a high-fat food (a candy bar) prior to the task. The amount of distraction by the high-fat food images was significantly less than distraction by images of low-fat foods and images of non-food objects, resulting in a significant interaction across the two experiments. These results (replicated in a second pair of experiments) demonstrate that while naturally occurring goal states can be difficult to ignore, they are also highly flexible.

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55.24, *6:00 pm* **Are visual threats prioritised in the absence of awareness? Evidence from a meta analysis and attentional cueing experiment.** Nicholas Hedger[1](naah1g08@soton.ac.uk), Katie Gray[2], Matthew Garner[1], Wendy Adams[1]; [1]Psychology, University of Southampton, UK, [2]Psychology, University of Reading, UK

Evolutionary theories suggest that humans can evaluate and prioritise emotionally salient stimuli, irrespective of whether they reach awareness. Many behavioral observations support this idea. Studies using the masked visual probe (MVP) paradigm suggest that threatening stimuli, rendered invisible by backward masking, can nonetheless capture spatial attention. Other studies suggest that threatening stimuli are preferentially processed, even when suppressed from awareness via binocular rivalry (BR) or continuous flash suppression (CFS). We provide a meta-analysis of the evidence for a threat-related advantage provided by these three paradigms. The CFS paradigm produced inconsistent effects; some types of threat stimuli were prioritised, whereas others were disadvantaged, relative to neutral stimuli, yielding an overall null effect. In the BR paradigm, the pooled effect size was medium, but was associated with conditions likely to induce response biases (e.g. piecemeal rivalry). The overall effect size from the MVP paradigm was small, with substantial heterogeneity explained by stimulus presentation time. Moreover, this dependency (possibly reflecting unintended stimulus visibility) was larger when the study failed to objectively measure stimulus awareness. This suggests that inadequate awareness measures and partial stimulus visibility may have contributed to the reported threat-related advantages. To investigate these issues, we conducted a well-powered visual probe study (N=41) with stimuli presented under normal conditions (conscious viewing: 500 ms), under backward masking (17 ms) and under CFS (500ms). Awareness of stimuli was assessed via stringent signal detection criteria. Although emotionally salient stimuli elicited attentional cuing effects under normal conditions, we detected none under masked or CFS conditions. Moreover, increased awareness of the stimuli in CFS and masked trials (assessed via a 2-alternative forced choice location task) predicted increased attentional cuing. Considered alongside our meta-analyses, our data suggest that attentional orienting to emotionally salient stimuli is dependent on, or at least strongly modulated by, their conscious registration.

55.25, *6:15 pm* Affective penetration of vision: Behavioral and eye-tracking evidence that emotion helps shape perception

Briana Kennedy[1](b.kennedy@student.unsw.edu.au), Daniel Pearson[1], David Sutton[1], Tom Beesley[1], Steven Most[1]; [1]School of Psychology, UNSW Australia

It recently has been claimed that no evidence yet supports a role of “top-down” factors, such as emotion, in perceptual processing (Firestone & Scholl, in press). Here, we provide evidence supporting such a role by probing an effect known as “emotion-induced blindness” (EIB) – i.e., the disruption of target detection within an RSVP sequence by emotional distractors. Initially assumed to stem from post-perceptual disruption or competition, EIB appears to be spatially localized, suggestive instead of spatiotemporally driven, perceptual competition between targets and meaningful distractors. When two RSVP streams of stimuli appear simultaneously, emotional distractors primarily impair perception of targets that appear in their same location, not of targets that appear in a different location – opposite the spatial pattern that would be expected if EIB stemmed simply from peripheral attentional selection. However, an alternative explanation may be that this spatial pattern results merely from where participants look during the task (e.g., distractors might cause disruption when fixated, but not be processed otherwise). To disentangle these accounts, we employed gaze-contingent eye-tracking in order to position distractors in the fixated or non-fixated stream. EIB was localized to the distractor location regardless of fixation, consistent with a spatiotemporal competition account. In order to additionally disentangle roles of perceptual competition and memory encoding, participants in a second experiment were required to remember distractors. In this case, emotional distractors disrupted target perception across both streams but this impact was still greater at the distractor location (regardless of fixation), suggesting that the roles of perceptual competition and memory encoding in emotional disruption of target processing are additive. Together, these findings suggest that emotion processing helps shape perception via mechanisms beyond peripheral attentional selection and disruption of memory encoding.

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55.26, *6:30 pm* Spatial reward guides choice, not visual search

Andrew Leber[1](leber.30@osu.edu), Bo-Yeong Won[1]; [1]Department of Psychology, The Ohio State University

The influence of reward on human behavior is pervasive, extending to virtually all aspects of cognition. Much recent research has focused on how reward influences attention, producing consistent demonstrations that valuable stimuli command greater attention. However, one conspicuous exception has been spatial location; only a few studies have reported attentional prioritization of valuable spatial locations, while several others have failed to find any prioritization. These failures suggest that visual search is largely insensitive to spatial value. Here, we provide more rigorous tests of this possibility, comparing spatial reward learning during visual search to a novel “visual choice” task. During Visual Search (Experiment 1), participants searched for a target T among 15 Ls, responding with a speeded mouse click on the target. Targets in a pre-designated “high value” quadrant yielded 20 points on 75% of trials and 1 point on the remaining trials; targets in the other “low value” quadrants yielded the opposite payoff ratio. We informed participants that points translated to monetary earnings but did not describe the spatial value contingencies. Results replicated previous work, showing no search bias toward the high-value quadrant. The Visual Choice task (Experiment 2) used virtually identical displays, except all 16 items were Ls. Participants clicked on any L and received a reward determined by the same quadrant contingencies as Experiment 1. Here, participants rapidly developed a strong choice bias toward the high-value quadrant. In Experiment 3, to rule out potential effects of priming, task context, and learning differences, we alternated 16-trial mini-blocks of the Search and Choice tasks. Strikingly, the participants preserved no spatial bias during search and a strong bias during choice. Thus, even if spatial rewards are learned (i.e., during visual choice), they are not transferred to visual search. Consequently, our visual search apparatus appears to be insensitive to spatial value.

55.27, *6:45 pm* If you see something, say something: Event monitoring capacity is low.

Chia-Chien Wu[1,2](cchienwu@gmail.com), Abla Soce[2], Jeremy Wolfe[1,2]; [1]Harvard Medical School, [2]Brigham & Women’s Hospital

In many surveillance situations, observers monitor for an event (e.g. Did anyone abandon a bag?). In multiple object tracking (MOT), humans can track ~4 pre-specified objects among distractors. What is our capacity for “event monitoring” and how does it relate to MOT capacity? In four experiments, observers tracked 2,4,6,8 moving items. Their task was to detect a state change in a one, unspecified object. Observers monitored all items. In the first experiment, items were Ts or Ls. The target event was a change in one letter from T to L or vice versa. In the second experiment, all items were unique objects, and the target would experience a state change (e.g. open book shuts). In Experiment 3, half of the items were disks “carrying” black round ‘bags’ while the other half were identical disks having no bag (Experiment 3). In Experiment 4, half the disks carried black square bags and the other half carried blue round bags. The target event was either one disk passing a bag to another (Exp3) or two disks swapping bags (Exp4). In all experiments, observers responded immediately once they found the target. Targets were counted as missed if observers did not respond within 2 seconds after the change occurred. Performance was better when there was only one type of change (TvsL, Exp1, capacity 3.3) than when each item and change was unique (Exp2, capacity 2.5, p = 0.01). The bag swap experiments produced similar capacities (2.4 items). Interestingly, RTs were markedly faster in Experiments 3&4, suggesting a different strategy for monitoring for part changes than for identity or state changes. However the results are explained, it seems that human observers have a very limited ability to monitor groups for critical events – a limit seemingly related to the working memory and multiple object tracking limits.

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55.28, *7:00 pm* Irrational vision: Behavioural and fMRI studies of economic framing in naturalistic visual search

Clayton Hickey[1](clayton.hickey@unitn.it), Ludwig Barbaro[1], Marius Peelen[1]; [1]Center for Mind / Brain Sciences, University of Trento, Italy

Rational economics suggests that a gain should have the same value as evasion of equivalent loss. But Kahneman and Tversky famously showed that in decision making this is not the case: how we frame the outcome matters. Is vision equally irrational? Recent studies have shown that stimuli associated with monetary reward come to draw selective attention. If this reflects a rational bias toward objects providing outcome-predictive information, stimuli predicting both gain and the evasion of loss should be prioritized. To test this hypothesis, we cued participants to detect examples of object categories – cars, trees, houses, and people – presented in images of natural scenes. For each category, correct performance resulted in reward (+150 vs. +50), the avoidance of greater loss (-50 vs. -150), or neutral outcome. We modelled results according to two predictions: if selection is driven by a bias toward outcome-predictive stimuli, both predictors of reward and of the avoidance of loss should draw attention equally well. But if selection is driven by gain, only gain-associated stimuli should be prioritized. In a behavioural experiment performance closely followed the gain-only model: accuracy was high when targets predicted reward and low when targets predicted loss avoidance. Moreover, reward-predictive stimuli disrupted search when they acted as distractors but stimuli predicting loss avoidance were easy to ignore. In a subsequent fMRI decoding study we

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observed the same pattern in the quality of stimuli representations in ventral visual cortex. Stimulus-evoked activity in the dopaminergic midbrain also followed the gain-only model, such that activity in this area predicted the quality of visual representation. The association of reward to a category of stimuli thus appears to have an effect on visual cognition that is economically irrational and independent of the drive to seek information.

Tuesday Afternoon Posters

Color and light: Neural mechanisms

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

56.3001 Phosphene perception from transcranial magnetic stimulation (TMS) over the vertex

Kelly Webster[1](websterk3@gmail.com), Tony Ro[1]; [1]Psychology, The Graduate Center, CUNY

TMS, a technique that disrupts neural processing and can induce the perception of flashes of light (i.e., phosphenes) by stimulation of visual areas, is a valuable tool for studying the mechanisms underlying human visual perception. Recent studies claim that phosphenes can be induced even by parietal stimulation (Marzi et al., 2009; Fried et al., 2011; Mazzi et al., 2014; Bagattini, Mazzi, & Savazzi, 2015), raising concerns about the many studies that use the parietal lobe or vertex as control sites to rule out non-specific effects of the TMS. In this study, we assessed whether phosphenes induced by TMS of the vertex are likely to be a consequence of current spread into the retina or visual cortex. TMS was applied over V1 or the vertex at intensities that reliably produced phosphenes over V1 and found that subjects with smaller head circumferences reported a nearly threefold increase in perceiving phosphenes from vertex stimulation compared to subjects with larger head circumferences. In contrast, there was no significant difference between these two groups in the percentage of phosphenes reported from V1 stimulation. Because distinct phosphenes cannot be reliably induced from TMS of the retina, these results strongly suggest that phosphenes perceived from TMS of the vertex or parietal cortex arise from current spread into nearby visual cortex and indicate that the use of the vertex as a control site for TMS experiments of visual perception may be highly problematic.

Acknowledgement: NSF

56.3002 Blue-yellow biases in early visual cortex assessed by VEP's

John Erik Vanston[1](jvanston1206@gmail.com), Alissa Winkler[1], Michael Webster[1], Michael Crognale[1]; [1]Psychology Department, University of Nevada - Reno

Sensitivity in many perceptual tasks tends to be weaker along bluish-yellowish axes than along reddish-greenish axes that are chosen to have equivalent modulations along the LM and S cardinal axes, pointing to a "higher-order" representation of color. We examined whether this bias is manifest in the visual evoked potential (VEP), a measure that can potentially disambiguate early vs. late processing in visual cortex. Subjects fixated the center of the screen while passively viewing fields of gratings that were modulated along different axes in a cone opponent space that was scaled to roughly equate sensitivity to LM and S and was adjusted for equiluminance for individual observers. These axes included nominal bluish-yellowish axes (e.g. 135º-315º), and an orthogonal reddish-green axis (45º-225º). Contrast along each axis was varied over a wide range of levels in a 200ms onset, 800ms offset design, with different axes randomly interleaved. VEP's were recorded at site Oz and referenced to site Pz according to the 10-20 electrode placement system. For each chromatic direction, a function was fit to the subjects' peak-to-trough response amplitudes. Criterion thresholds were taken as the contrast at which the response reached two times the noise level for each axis, and were well above the observer's detection thresholds. The iso-response contours were significantly elevated along the blue-yellow axis relative to the reddish-green axis, $t(8) = 5.35$, $p = 0.001$. Notably, we also observed a large asymmetry within the blue-yellow axis, such that yellowish-orange directions had higher thresholds than their bluish counterparts. The weaker sensitivity to blue-yellow is consistent with other recent work (e.g. Goddard et al. 2010) pointing to a non-cardinal bias in early cortical color coding, and may reflect a further signature of cortical adaptation to the stronger blue-yellow variations in natural scenes and lighting.

Acknowledgement: Supported by EY10834

56.3003 In search of a melanopsin contribution to the ERG: Reconceptualizing the source of the a-wave?

Christopher Tyler[1](cwt@ski.org), Lora Likova[1], spero Nicholas[1]; [1]Smith-Kettlewell Eye Research Institute, San Francisco

Introduction. It is generally understood that the full-field dark-adapted ERG is dominated by the scotopic spectrum of the rod response (Holopigian et al., 1992; Hood & Birch, 1992), although short-wave anomalies have been reported that could be attributed to a melanopic component (e.g., Bierdsdorf & Grand, 1962), and fast melanopic ERG responses have been reported in silent substitution protocols (Fukuda et al., 2010). Moreover, long-wave anomalies in the ERG have long been known in the form of the short-latency x-wave (Adrian, 1946; Armington, 1952). Methods. We examined the spectral sensitivity of the a/b-wave complex in human ERGs recorded with skin electrodes across the spectrum over three log units of intensity. Results. The long-latency component at all test wavelengths and intensities conformed to a single function of scotopic intensity (rod quantum catch), which we term the "main sequence" for ERG times-to-peak as a function of intensity. However, responses to red lights showed an extra short-latency peak (x-wave) at high intensity attributable to cone responses. Nevertheless, rescaling the data as a function of photopic intensity did not result in a clean alignment of the a-waves across the spectrum, as would be predicted by the cone attribution. The a-wave latencies, however, became aligned by scaling the data as a function of equal-energy radiance. Conclusion. The results suggest a reconceptualization of the spectral sensitivity of the dark-adapted cone a-wave (and the subsequent x-wave) as neither photopic nor scotopic, but conforming to the radical hypothesis that the a-wave responses throughout the spectrum derive from a pre-luminance sensitivity to the radiant energy impinging on each class of photoreceptor. This radiant energy baseline provides a firm basis for assessing the melanopsin contribution to the ERG response.

Acknowledgement: CDMRP grant #W81XWH-14-1-0416

56.3004 Influences of sunrise and morning light on visual behavior of four sympatric New World primates (Alouatta, Ateles, Callicebus, Lagothrix)

Max Snodderly[1,2](max.snodderly@austin.utexas.edu), Kelsey Ellis[1,2], Sarina Lieberman[1,2], Andrés Link[2,3], Eduardo Fernandez-Duque[4], Sara Alvarez[5], Laura Abondano[1,2], Anthony Di Fiore[1,2]; [1]University of Texas at Austin, [2]Fundación Proyecto Primates, [3]Universidad de Los Andes, [4]Yale University, [5]Universidad Regional Amazónica IKIAM, Ecuador

Among New World primates, only one genus out of 18 is known to have routine trichromatic color vision like humans. All other species investigated to date have diverse color vision genotypes that suggest potential diversity in their visual ecology. Some evidence indicates that different color vision phenotypes, particularly dichromats, may be more successful when foraging in dim light. Using light spectra measured during the transition from darkness to daylight, and behavioral data collected during ongoing studies, we analyzed the timing of first vocalizations and first foraging in relation to ambient light for four sympatric primates at the Tiputini Biodiversity Station in Amazonian Ecuador. Across taxa, we found no evidence of activity occurring before the onset of nautical twilight (~48 min before sunrise). Observers on the ground frequently thought that monkeys began their morning activity in darkness, but measures of the quantum flux between 400 and 700 nm showed that only 1-2% of the light at canopy level reaches the ground, so the light available to the animals is ~2 log units higher. Day-to-day variation in cloud cover had large effects on available light, producing a 1.6 log unit range in quantum flux at sunrise. First vocalizations of Alouatta and Callicebus often occurred before sunrise, while those of Ateles and Lagothrix were usually later. First feeding bouts usually began later than vocalizations, and were more widely distributed in time. For example, woolly monkeys (Lagothrix) usually waited until after sunrise (mean 49 min) to feed. Human observers at canopy level were able to distinguish colors at 21-23 min before sunrise, so it appears that the monkeys are waiting for good viewing conditions before feeding. Ongoing analyses are investigating temporal relationships between feeding bouts, measured light levels and other ecological factors for these species.

Acknowledgement: NSF IOS-0843354, BCS-1062540, and BCS-1540403

56.3005 Afterimages and Induced Colors Have the Same Hue: Implications for Discounting Illuminants

Gennady Livitz[1](glivitz@gmail.com), Guillaume Riesen[2], Tim Shepard[3], Ennio Mingolla[1], Rhea Eskew[3]; [1]Communication Sciences and Disorders, Bouvé College of Health Sciences, Northeastern University, [2]School of Medicine, Stanford University, [3]Psychology Department, College of Science, Northeastern University

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Human vision strives to make the perceived color of objects relatively unchanged under shifts in illumination – a capacity termed "color constancy". To discount the chromaticity and intensity of illumination the visual system must estimate it from light reflected from surfaces in areas surrounding a target object, and from past stimulation. These computations are done by neural mechanisms of spatial color contrast and temporal adaptation. Temporal adaptation may cause a visible afterimage, the hue of which is approximately complementary to that of the adapting stimulus. Similarly, color contrast may shift color in a direction that is approximately complementary to its surround. We probe cone excitation space, by modulating stimuli along the ±(S-cone) and ±(L-M) as well as other chromatic axes, to characterize low level mechanisms involved in discounting illumination. We use asymmetric color matching to measure the chromaticity produced by spatial induction and of afterimages. Results show that neither afterimages (Loomis, 1972) nor spatially induced colors are actually complementary to the colors of the inducing stimuli. The important exceptions are ±(L-M) stimuli, which do produce complementary afterimages and complementary spatial chromatic induction. In all cases, the match to the color that is spatially induced has the same relative S/(L-M) difference from complementarity as the color that matches the afterimage, indicating that afterimages and spatially induced color have the same hue. That this hue is complementary only for stimuli that do not modulate S-cones strongly suggests an interaction of cone systems that can only be explained by a subtractive postretinal process, one that requires S cone contributions to multiple pathways -- contradicting the cardinal axis model. The data show that these S cone contributions are relatively the same for both afterimages and spatial chromatic induction and lead to a model framework for the mechanisms that discount changes in illumination.

Acknowledgement: Rhea Eskew was supported by NSF BCS-1353338

56.3006 **Suprathreshold interactions between color and luminance contrast: the effect of cross-oriented luminance contrast on perceived color contrast under dichoptic, monocular and binocular viewing conditions** Yeon Jin Kim[1](yeon.jin.kim@mcgill.ca), Kathy Mullen[1]; [1]McGill Vision Research, Dept. of Ophthalmology, McGill University

Natural scenes contain both color and luminance contrast at different spatial scales and orientations that are sometimes spatially overlaid and sometimes not. Hence, the study of the interaction between color and luminance contrast is fundamental to a complete understanding of visual processing. Such interactions have been well established at the level of detection thresholds, revealing that responses to color and luminance behave independently and are attributable to separable neural processes. Here we investigate suprathreshold interactions between overlaid color and luminance contrasts presented orthogonally (cross-oriented) to reveal how luminance contrast affects the contrast normalization of perceived color contrast. Method: We tested the effects of an overlaid luminance contrast pattern on the perception of color contrast using a method of constant stimuli to determine a Point of Subjective Equality (PSE) between color-only and color plus luminance contrast for binocular, monocular and dichoptic viewing conditions across a range of spatial frequencies (0.375-1.5 cpd, at 2Hz). Results: Our results show that overlaid luminance contrast affects the perceived color contrast, and that the effect is markedly different across viewing conditions. For binocular and monocular viewing, the interaction is facilitatory, with overlaid, cross-oriented luminance contrast enhancing the saliency of perceived color contrast by up to 40-50%. For the dichoptic viewing, however, the interaction is inhibitory, with the luminance contrast suppressing color contrast interocularly. Conclusions: We propose that the underlying mechanism mediating the chromatic facilitation exists as an excitatory within-eye route that carries forward to binocular site, and that a suppressive interocular route may also modulate responses via a binocular site.

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56.3007 **Attentional modulation of color representation in human lateral geniculate nucleus** Sang Wook Hong[1](shong6@fau.edu), QIng Yu[2], Won Mok Shim[2]; [1]Department of Psychology, Florida Atlantic University, [2]Psychological and Brain Sciences, Dartmouth College

Studies on the non-human primate visual system show a strict distinction between two cardinal chromatic channels, parvocelluar (L-M) and koniocellular (S-(L+M)), in neuronal responses of the lateral geniculate nucleus (LGN), which may result in a limited color representation at LGN level. Using functional Magnetic Resonance Imaging (fMRI) in conjunction with a forward encoding model (Brouwer & Heeger, 2009), we investigate first, whether both cardinal and inter-cardinal colors can be represented in the human LGN, and second, whether these color representations can be modulated by selective attention. On each block, observers viewed equi-luminant concentric ring patterns, composed of either one of four cardinal colors varying on only one channel or four inter-cardinal colors varying on both channels, and equal-energy-spectrum white, which drifted alternately in expanding and contracting directions. Observers performed either a central RSVP task (attention to fixation condition) or a color discrimination task (attention to color condition), which were alternated between blocks within each experimental run. Observers were instructed to report the target (letter 'J' or 'K') among other letters in the central RSVP task and to detect near-threshold level (measured for individual observers and for each color separately) changes in color in the color discrimination task. We found that attention can modulate the population-level color tuning responses to both cardinal and inter-cardinal colors. Our results demonstrate that both cardinal and inter-cardinal colors can be represented at the LGN level and that attentional feedback alters population-level responses to chromatic information in the LGN.

56.3008 **Factors underlying individual differences in hue scaling** Kara Emery[1](karaemery@nevada.unr.edu), David Peterzell[2], Vicki Volbrecht[3], Michael Webster[1]; [1]Psychology Department, University of Nevada, Reno, [2]Psychology Department, John F. Kennedy University, [3]Psychology Department, Colorado State University

The number and nature of the mechanisms mediating color appearance remain poorly understood. We used factor analysis to examine the patterns of individual variation in a previous study of hue scaling measurements reported for 59 color-normal observers (Malkoc et al. JOSA A 2005). The settings involved judging the strength of red, green, blue, and yellow percepts for 24 equiluminant stimuli spanning a circle at 15 deg steps in a version of MacLeod-Boynton color space (scaled to equate sensitivity along the LM and S axes). Three observers were excluded based on inconsistent settings. A factor analysis with Varimax rotation was performed for the remaining 56, and revealed a large number of systematic but narrowly tuned and unimodal factors, spaced roughly evenly across hue angle. Together these accounted for a large proportion of the variance (80% for the first 8), while the variance attributable to any individual factor was relatively low (8-15%). Separate factors emerged for reddish and greenish hue angles, and for blue and yellow, indicating that the two poles of the putative opponent axes varied independently. Moreover, additional independent factors occurred for intermediate hue angles corresponding to purple, cyan, or orange regions. Our analysis confirms previous evidence that inter-observer differences in color percepts vary independently not only for the unique hues but also for the intermediate or putative binary mixtures. The pattern is inconsistent with the predictions for individual variations in conventional opponent mechanisms (e.g. in their preferred color axis or sensitivity), and instead suggests the presence of multiple, higher-order mechanisms underlying color percepts, even when observers are restricted to describing these percepts only in terms of the four unique hues. Supported by EY-10834

56.3009 **Hue and slew** Andrew Stockman[1](a.stockman@ucl.ac.uk), Bruce Henning[1], Andrew Rider[1], Peter West[1], Caterina Ripamonti[1]; [1]UCL Institute of Ophthalmology

When alternated at low temporal frequencies pairs of coloured lights usually appear to vary in hue at their alternation frequency. As the frequency is increased, the hue variation fades to a steady mixed-hue appearance at frequencies well below the flicker fusion frequency, but a luminance variation of the mixed-hue remains (unless the alternating lights are luminance-equated). Traditionally, this loss of hue variation at relatively low frequencies has been assumed to reflect chromatic mechanisms' having greater temporal integration than the luminance mechanism. For several years, our group has been accumulating evidence for an alternative model that postulates that the hue variation is partly limited by the rate at which chromatic mechanisms can signal changes in hue (i.e., they are a limited by a "slew" rate). Our approach has been to vary the temporal waveform of flicker in ways that give rise to predictable changes in either the mean ("DC") hue appearance or the time-varying ("AC") hue variation that should result from a slew limit. These waveforms include sawtooth stimuli that vary in their on- and off-slopes from rapid-on to triangular to rapid-off, square-wave stimuli that vary in duty-cycle, combinations of 1st and 2nd harmonic sinusoidal flickering lights that vary in phase, and other more complex waveforms. The objective psychophysical tasks have included detection and matching of the DC and/or AC components. We have compared these psychophysical data with simulations. We find that a model in which the slew rate limit follows an expansive nonlinearly that accelerates input signals above and below the mean can account for many of the phenomena we have encountered in terms of changes to both the DC and the AC. Moreover, slew-rate models in which different unipolar or bipolar hue mechanisms have different slew rates may provide the basis for explanations of pattern induced flicker colours.

Acknowledgement: BBSRC

56.3010 A New Approach to the Absorption of Photon Energy among Retinal Cells Provides the Key to Some Old Problems in Color Vision

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The standard method of calculating cone response fails to capture the variability of absorbed energy among cells. Two identical cone cells of the same type exposed to the same uniform light absorb different amounts of energy. We have derived a distribution for the fractional number of cells absorbing different levels of energy and we find that this distribution implies a limit to the magnitude of chromatic induction. We studied chromatic induction using a small disk, approximately neutral (CCT of 2700 Kelvin), located within a homogenous background that filled the entire visual field. The surround was illuminated with red light of luminance 15 cd/m2. Subjects' task was to neutralize the induced color by nulling. Six surround saturation levels were used with both decremental and equiluminant targets. In agreement with Kirschmann's fourth law, we observed that as surround saturation increases, induction increases, but induction rate falls off, although, the form of the falloff is still not well understood. To analyze the extent to which red light was added to the target disk to make it appears neutral, the Bhattacharyya distance between bivariate distributions of chromaticities for the neutralized and white targets was calculated. We observed a residual amount of overlap between chromaticities of the neutralized and white targets at different surround saturations. This result indicates that the variation of energy distributed among cells stimulated by light from the target imposes a limit to the magnitude of induction. We suggest that a plausible mechanism for the effect is the distortion of target cells' energy distribution by the surround color stimulation, which results in altering the balance of photoreceptor signals toward the induced color. This observation, derived from statistical representation of energy distribution among cells, would not be possible with the conventional representation in which color is quantified by single values of cone responses.

Acknowledgement: NSF funding (BCS-1230793)

56.3011 Retinal Processing Optimizes Contrast Coding

Jihyun Kim[1](jihyun.kim@upf.edu), Thomas Batard[1], Marcelo Bertalmío[1]; [1]Information and Communication Technologies, Universitat Pompeu Fabra

The properties of human contrast perception show a close correlation to the responses of retinal ganglion cells (Kelly, 1977; Lee, 1990), whose spatial processing properties (the isotropic center-surround processing) are shaped by the local feedback from interneurons (horizontal / amacrine cells) to the feed-forward cells (photoreceptor, and bipolar / ganglion cells). In the current work we investigated the computational structure of this retinal feedback system. We first identified a simple form of a system of differential equations that realizes the retinal feedback architecture and analyzed its steady-state behaviour to a static stimulus input. Three main conclusions may be derived from the results of the analysis. Firstly, the system of equations preserves the ability to predict some human contrast perception properties such as spatial-frequency dependent contrast sensitivity and brightness induction (contrast and assimilation) as other existing retinal models predict (Kim & Bertalmío, 2015; submitted; van Hateren, 2007; Wilson, 1997), thus showing a minimum computational structure to emulate human contrast perception engendered at the retina. Secondly, the steady-state response of the system can be obtained in a single pass by convolving the original input with a single kernel (a combined product of different extents of receptive-fields of the retinal cells) and therefore our work proposes a computationally efficient way of modeling retinal cell responses and the resulting human contrast perception. Finally, finding the steady state solution is mathematically equivalent to solving an optimization problem of maximizing the spatial contrast in the encoded signals while being faithful to the local light intensity of the input stimulus, which suggests interesting connections with efficient coding theories and computational neuroscience models like the Wilson-Cowan equations (see Bertalmío, 2014). Our results shed light on the computational goal of the feedback architecture in the retinal circuit: an optimized representation of the spatial contrast in the incoming light pattern.

Acknowledgement: This work was supported by the European Research Council, Starting Grant ref. 306337, by the Spanish government, grant ref. TIN2012-38112, and by the Icrea Academia Award.

56.3012 Dissociating Electrophysiological Correlates of Luminance and Brightness Using Metacontrast Masking

Bruno Breitmeyer[1](brunob@uh.edu), Maximilian Bruchmann[2]; [1]University of Houston, Houston, Texas USA, [2]University of Münster, Münster, Germany

Physical stimulus luminance and perceived brightness are typically highly correlated. It is therefore a methodological challenge to dissociate neural processes that scale with a stimulus's luminance from those that scale with its phenomenally perceived brightness. With a metacontrast masking paradigm we exploited the fact that metacontrast masks varying in luminance can differentially modulate the association between a target's luminance and its perceived brightness. Target contrasts were 6.25, 12.5, 25, 50 and 100%. Subjective ratings assessed the perceived brightness of each target when its visibility was suppressed by a weak, 12.5%-contrast mask and when it was suppressed by a strong 100%-contrast mask. The difference between the brightness ratings obtained with the two masks was computed for each of the five target contrasts and were then correlated with corresponding differences between the post-target EEG waveforms. We found that low-level occipital activity originating 80 ms and spreading in feedforward manner along the ventral and dorsal visual stream until 120 ms after target onset scaled with stimulus luminance. In contrast, first neural correlates of brightness (NCBs) emerged from 120 to 150 ms after target onset, predominantly in the right superior parietal lobe. From 160 to 180 ms NCBs emerged in the left temporal lobe and spread via feedback towards primary visual areas, from where they in turn spread to parietal and temporal areas again. The results suggest that the first feedforward sweep is defined by physical stimulus features, but that already after 120 ms recurrent activity involving parietal attention- and ventral object recognition-related areas scales with the perceptual outcome, rather than the physical input. No neural activity originating in frontal areas correlated with either the luminance or the perceived brightness of the target, suggesting that frontal activation is not necessary for stimuli to register in phenomenal awareness.

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56.3013 Brain mapping reveals potential functions of ipRGCs in modulating eye movements

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Intrinsically-photosensitive retinal ganglion cells (ipRGCs) that express melanopsin are well-known for mediating non-visual functions such as entrainment of circadian rhythms and the pupillary light reflex. However, the cerebral neural correlates of ipRGC-specific signals in healthy humans remain largely unknown. Here, using functional magnetic resonance imaging (fMRI) and light stimuli designed to differentially activate melanopsin, we examined brain responses associated with ipRGCs photoreception in 14 healthy participants. In order to control for the involvement of rods and cones, we designed pairs of perceptually similar white lights (metamer-like lights) with high and low levels of melanopic excitation (High_Mel versus Low_Mel) while having minimal excitation differences for cones and rods. We discovered that, at high melanopic excitation (when ipRGCs were more excited), bilateral frontal eye field regions showed stronger activation. Multivariate pattern analyses (MVPA) further yielded distinct bilateral pattern activity in the inferior temporal gyri and caudate nuclei, both have been reported receiving inputs from the frontal eye fields. Enlightened by these findings, we hypothesized that ipRGCs may influence eye movements and therefore conducted an eye tracking experiment to test this hypothesis. The results showed that participants exhibited larger fixational eye movements in the horizonal dimension while ipRGCs were more activated. Taken together, these findings suggest that light flux detection by ipRGCs activate cerebral regions classically involved in attentional and ocular motor responses and lead to greater magnitudes of fixational eye movement.

56.3014 Factor analysis of individual differences in the spectral sensitivities of transgenic and wild-type mice: expression of wild-type (M) and human (L) cone photopigments

David Peterzell[1](davidpeterzell@mac.com), Michael Crognale[2]; [1]John F. Kennedy University, [2]University of Nevada, Reno

Shabaan et al. (1998) were the first to examine how a newly added human cone photopigment could affect vision in genetically modified mice. They established that the human transgene for human long wavelength sensitive (L) photopigment was expressed in mouse cones, and that the pigment was efficient at transducing light. Following earlier modeling approaches (Webster & MacLeod, 1988; Peterzell, 1991), we factor-analyzed individual differences in the spectral sensitivity data of Shabaan et al. to (1) measure independent expression of M and L photopigments, and (2) extract estimates of their absorption spectra. Flicker-electroretinogram (ERG) responses from five wild-type controls and five transgenic mice were recorded at 15 and 19 wavelengths (460 to 640 nm). Visual inspection of spectral sensitivity functions revealed one factor for wild-type mice, and two for transgenic mice. Pearson correlations (r) revealed the same. Principal component analyses of covariance matrices confirmed that one- (wild-type) and two-factor (transgenic mice) solutions accounted for >97% of individual variability. Varimax-rotated ("simple structure") factor loadings for transgenic mice were bipolar, consistent with underlying absorption spectra for M and L photopigments with zero-crossings at deuteranopic and tritanopic confusion points (equal M or L responses in test and standard). Two transgenic mice showing maximum contribution from the L factor descended from a founder that had two copies of the human L-pigment gene. The other three descended from second founder with only a single copy. Individual differences in the L factor were therefore consistent with relative expression of the transgene into mRNA and transgene copy number in retinas of two founder lines. While Shabaan et al. demonstrated functional separability of L and M photopigments using chromatic adaptation, our analysis confirmed and directly estimated spectra. More generally, we demonstrated that flicker-ERG data contain little error variance, so small samples of high-quality data can yield unequivocal factor-analytic results.

56.3015 **The invariance of surface color representations across illuminant changes in the human cortex** Michael Bannert[1,2,3](mbannert@tuebingen.mpg.de), Andreas Bartels[1,2]; [1]Werner Reichardt Centre for Integrative Neuroscience, University of Tübingen, [2]Bernstein Center for Computational Neuroscience Tübingen, [3]International Max Planck Research School for Cognitive and Systems Neuroscience

Color is the brain's estimate of reflectance for a given surface. Reflectance describes how much light a surface reflects at different wavelengths. Since the light reflected from a surface depends on its reflectance and on the spectral power distribution of the incident light, it is impossible to predict surface reflectance directly from the wavelength composition of the reflected light. Despite this computational problem, the human visual system is remarkably accurate at inferring the reflectance – perceived as color – of surfaces across different illuminants. This ability is referred to as color constancy and it is essential for the organism to use color as a cue in object search, recognition, and identification. We devised images of two surfaces presented under three different illuminants using physically realistic rendering methods to study the neural architecture underlying surface color perception. Measuring patterns of fMRI voxel activity elicited by these images, we tested to what extent responses to surface color in various retinotopically mapped areas remained stable across illuminants and which regions encoded illuminant information. We made three important observations: First, patterns of fMRI responses to surface color generalized across illuminants in V1 but not V2, V3, hV4, or VO1. Second, accuracy of illuminant decoding was positively correlated with psychophysically measured color constancy as predicted by the Equivalent Illuminant Model. Third, when fMRI activity was elicited by stimuli that were matched in reflected light but differed in illumination and therefore also differed in perceived surface color, there was a gradient from lower to higher visual areas to distinguish between the two inputs in terms of a difference in surface color rather than illumination. Our results demonstrate that V1 represents chromatic invariances in the stimulus environment (possibly via feedback) whereas downstream visual areas are more biased to link chromatic differences to different surface color percepts.

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56.3016 **Measuring the Propagation of Neural Signals Evoked from Colors and Contours** Andrew Coia[1](andrewcoia3@gmail.com), Michael Crognale[1]; [1]Cognitive Brain Science, Psychology, University of Nevada Reno

Surface coloration can be achieved by physically coloring in a surface or alternatively by induction from edges. One visual illusion known as the watercolor effect demonstrates how color from edges can spread within a boundary. The coloration of the watercolor effect resembles a desaturated hue of the inducing line, or a mixture of the inducing line with the uncolored surface. It is debated whether this spreading of color is due to an active process of filling in the retinotopic maps in the cortex or through a more symbolic neural representation assigning color to a region of space. Both early visual as well as ventral occipital cortical areas are thought to contribute to the percept of color vision. The current study looks at neural processing associated with physical color vs. edge-induced colors using high density (HD) EEG source estimation. This method estimates the intensity and time course of activity on the surface of the cortex from which the electrode signals on the scalp are generated. We previously used steady state VEP to measure the watercolor illusion. We performed a similar HDEEG experiment with single black lines and in addition added a second colored line, which in an aligned state produced the watercolor illusion, and in a misaligned state produced a control stimulus with contours but no induction. Pattern reversals of two misaligned control stimuli were recorded as comparison. We inserted physical filled-in color to one of the two reversing controls and generated a fundamental color frequency independent of alignment. These SSVEPs were complemented with pattern onset VEPs which showed the stimulus followed by a blank screen. The onset VEPs show the propagation of the neural signal from early visual areas (V1/V2) to more ventral occipital areas. Further analysis on the SSVEP reveals phase propagation of contour alignment, illusion, and physical color.

Acknowledgement: The Bilinski Fellowship

Eye Movements: Visual search

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

56.3017 **The effect of Saliency and Ensemble in Visual Search.** Shunsuke Kumakiri[1](kuma@cv.jinkan.kyoto-u.ac.jp), Yoshiyuki Ueda[2], Jun Saiki[1]; [1]Graduate School of Human and Environment Studies, Kyoto University, [2]Kokoro Research Center, Kyoto University

A saliency-based visual attention model can simulate human eye movement. The higher saliency of the visual location, the more it attracts visual attention. While saliency map is computed from local information, ensemble information reflects spatially distributed objects. In this study, we examined whether ensemble information, in addition to saliency, influences human eye movements, and investigated the relationship between them. In the experiment, Gabor patches were placed in the left and right side of the screen with pink-noised background. The task was to count the point of Gabors (the black-white Gabor had 1 point and the colored Gabor had 2 or more points) and judge which side of the screen included just 20 points, during which their eye movements were recorded. We manipulated the difference in points between the left and right sides. In each trial, there was only one colored (the most salient) Gabor, which was located in the side with 20 points (congruent condition), or in the side with less than 20 points (incongruent condition). In the congruent condition, both saliency and ensemble information indicate the same side as target, whereas in the incongruent condition with large point difference, they indicate opposite sides as target. The results showed that participants' accuracy was consistently high in the congruent condition, whereas they increased from 57% to 94% as the point difference between sides of the screen increased in the incongruent condition. In the beginning of trials, eye movements in the incongruent condition were captured to the incorrect side, which has less than 20 points but included the colored Gabor. After a few saccades, their eyes moved to the correct side when the point difference was large. These results suggest that at first eye movements depend primarily on saliency, and ensemble information gradually affects them after a few saccades.

56.3018 **Target detection in dynamically changing visual displays: Predictive search, working memory capacity and intolerance of uncertainty** Alex Muhl-Richardson[1](amr2e13@soton.ac.uk), Hayward Godwin[1], Matthew Garner[1], Julie Hadwin[1], Simon Liversedge[1], Nick Donnelly[1]; [1]School of Psychology, University of Southampton

Many real-world visual search tasks involve interacting with dynamically changing displays of information. These must not only be searched but also monitored for change, demanding sustained attention and working memory resources. Display complexity may also entail high uncertainty regarding when and where targets will occur. Individual differences in working memory capacity (WMC), intolerance of uncertainty (IU) and target prediction may be important predictors of performance in such tasks. Participants completed a visual search for colour targets within dynamic displays while their eye movements were recorded. Trials contained arrays of 108 squares that changed between 16 colours at varying rates and responses were mouse-clicks on targets. Two experiments examined the limits of target prediction via manipulations of display dynamics, such that stimuli changed in ordered sequences through colour space, disordered sequences or randomly. To examine individual responses to uncertainty, a third experiment manipulated target prevalence and administered verbal/spatial 3-back WMC tasks and an IU questionnaire (IUS-12). As previously reported (Muhl-Richardson et al., 2015), under ordered dynamics, on average 49% of forthcoming targets were fixated pre-onset, but new data show this was significantly reduced when dynamics were randomised (24%) or disordered (7.97%). A significant effect of IU was observed upon false alarm rates (incorrect responses to non-targets) independently of target prevalence. Participants with greater IU made more false alarms and this relationship was moderated by WMC; those with higher WMC showed a reduced effect of IU. We conclude that: (1) predictive target detection is limited and requires the support of broad target templates that only operate when display dynamics incorporate order in colour space, rather than arising from learned probabilistic associations; (2) IU impedes target detection via a response bias towards target-similar stimuli to reduce uncertainty over forthcoming onsets; (3) high WMC moderates this effect through the availability of additional processing resources.

56.3019 **Search for targets in fixed or random locations within consistent routes** Oliver Tew[1](ot1e13@soton.ac.uk), Hayward Godwin[1], Matthew Garner[2], Julie Hadwin[3], Simon Liversedge[1], Nick Donnelly[1]; [1]Centre for Vision and Cognition, University of Southampton, [2]Psychology and Medicine, University of Southampton, [3]Developmental Brain-Behaviour Laboratory (DBBL), Psychology, University of Southampton

Does being able to predict forthcoming scenes facilitate target detection? We report a study that explores this issue. Targets were shown in 40 photographs of real-world scenes, with participants learning the set of photographs across eight presentations. The scenes were taken from positions along a route. The repeating sequences were structured to be consistent with that route (route consistent condition) or randomised (route inconsistent condition). In a previous study (VSS, 2015), we reported that route consistency did not influence target detection when targets appeared randomly across scenes and locations. In a new experiment, targets were always presented in particular scenes and, for some scenes, always presented in a particular location (though target identity was randomly determined). As in our previous study, the participants' task was to find and fixate targets. Accuracy, reaction times (RTs) and eye movements were measured. Basic behavioural data showed responses to absent trials to be slower but more accurate than present trials, while RTs and error rates reduced over block. Examining target location (fixed vs. varied) showed that errors reduced over blocks for targets in fixed positions only. There was no effect of presentation sequence (consistent vs. inconsistent) on RTs or accuracy. However, eye movement data showed that scene order reduced fixation durations on present trials for the route consistent condition only. Additionally, the time to first fixate targets was shorter in the fixed vs. varied location condition. This pattern was reversed in the time to verify targets. We conclude that the results show an influence of being able to predict forthcoming scenes on target detection. The ability to predict forthcoming real-world scenes and target location both influence search strategy. We add this finding to previously reported scene context effects (e.g. Brockmole & Henderson, 2006).

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56.3020 **Visual search in natural scenes: Normative modeling of the target absent case** Jared Abrams[1](jared@mail.cps.utexas.edu), Wilson Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Normative models of search provide a benchmark for evaluating human performance and identifying rational behavioral strategies. Previous work has identified the entropy limit minimization (ELM) observer as an optimal fixation selection model.1 The ELM observer selects fixation locations that maximally reduce uncertainty about the location of the target. We compare this with a maximum a posteriori (MAP) model, which selects fixation locations that have the greatest posterior probability of containing the target. Previously, these models were specified for the case where the target is always present. In natural tasks, a target may not be present in the scene. Here, we extend these models to produce predictions for the case where the target may be present or absent. Human observers participated in a search experiment where a target was present in a natural scene on half of the trials. Observers reported the location of the target or indicated its absence. Our observers required 2.25 times as many fixations to indicate target absent (9 fixations) versus target present (4 fixations) while maintaining a high degree of accuracy. Both the ELM and MAP models are faster and more accurate than human searchers. We scaled the single fixation map of detectability (d' map) in each model to match the hit rate (91.0%), correct rejection rate (90.8%), and median number of fixations (6.5) of the observers. We found that the ratio of target absent fixations to target present fixations was 2.5 for the MAP, compared with a value of 2.27 for the ELM. The similarity in the ratios of target absent fixations to target present fixations between the human and ELM observers suggests that the ELM describes human fixations in natural scenes better than the MAP. 1Najemnik, J. & Geisler W.S. (2009) Vis. Res., 49, 1286-1294.

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56.3021 **Tracking the dynamics of working memory representations through the eyes** Katya Olmos Solis[1](kos220@vu.nl), Anouk Van Loon[1], Christian Olivers[1]; [1]Vrije Universiteit Amsterdam

The search template is a specific type of visual working memory (VWM) representation that facilitates search by guiding attention toward matching features when they appear in view. In a series of experiments we tested whether the pupil response and microsaccades can be used to track attentional guidance by the search template and differentiate this process from recognition of other VWM contents. Participants memorized either one or two colored circles to be searched for later on. When two circles were presented, a retro-cue indicated which one of the two was relevant for the upcoming search task (the template). Crucially, before the search display appeared, we briefly presented one or two colored probe stimuli. These probes could match the color of either the relevant-template color, the irrelevant color, or it could be a new color unrelated to the items in memory. We measured the pupil response to the probe display and the amount of microsaccades to the template matching probe as a signature of attentional guidance. Overall, the pupil showed significantly more constriction in response to memory matching probes than for unrelated colors. However, this effect seems to be driven by the recognition of the memory items in the probe display rather than by the relevance of each item. In contrast, microsaccades were consistently directed towards probes matching the relevant color. Taken together, both the pupil and microsaccades were sensitive to when information was previously presented but only microsaccades could distinguish the search template from other VWM representations.

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56.3022 **Typicality effects in categorical visual search investigated using the pupillary reflex** Arryn Robbins[1](arobbins@nmsu.edu), Michael Hout[1]; [1]New Mexico State University

Each day, we look for things with imprecise information about the specific visual features that make up our target object (e.g., looking for any writing instrument). Recent evidence suggests that during such "categorical searches," observers may construct target templates from the features common to highly typical members of a category (e.g., "slender," "tapered tip;" Robbins & Hout, 2015). Here, we examined categorical templates by measuring the pupillary reflex, reasoning that pupil dilation reflects the degree of match (or "resonance") between incoming visual information and the searcher's template (Papesh, Goldinger, & Hout, 2012). If typical items are being used as templates, pupils should dilate more in response to typical category members (e.g., a pen), relative to atypical ones (e.g., a crayon). Participants completed two assessments of typicality: 1) a speeded category verification task, where participants indicated whether a basic-level item belonged to a superordinate category (e.g. "Are PANTS a member of CLOTHING?"). Fast verification times indicate high typicality. And 2) Likert ratings of typicality ("How typical are PANTS of the category CLOTHING on a scale of 1 to 7?"). During search, participants received a superordinate word cue followed by a RSVP stream of 5 grey-scaled pictures. Participants then indicated if a target was present or absent. Non-targets were selected from other superordinate categories (e.g. vehicles, plants). From each index of typicality, we identified low and high typicality members (based on a ternary split). For both measures of typicality, we found greater pupil dilation in response to high typicality objects relative to low typicality objects. This suggests that highly typical category members resonate more strongly with mental representations during search (relative to atypical objects). Our results provide additional evidence that target templates in categorical search may be derived from the most typical members of a category.

56.3023 **Rare Targets Induce Less "Perceptual Readiness:" Evidence from Pupillometry** Maggie Sabik[1](msabik@nmsu.edu), Collin Scarince[1], Megan Papesh[2], Hayward Godwin[3], Stephen Goldinger[4], Michael Hout[1]; [1]New Mexico State University, [2]Louisiana State University, [3]University of Southampton, [4]Arizona State University

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In visual search, targets that appear infrequently are missed disproportionately often, relative to those that appear more frequently. This "low-prevalence effect" (LPE) has significant societal consequences (e.g., missed tumors or weapons in applied screening contexts), and is challenging to alleviate. Previous eye-tracking research has demonstrated that low-prevalence targets are often missed even when they are directly fixated. The LPE has been attributed to several non-mutually exclusive mechanisms, including criterion shifts, search termination errors, and reduced priming for lower-prevalence targets. However, using passive (RSVP) search tasks, we previously found that the LPE persists even when searchers do not terminate search on their own. This suggests that low-prevalence targets have a weaker target template than their higher-prevalence counterparts (Hout et al., 2015). Here, we investigated low-prevalence misses by adopting a new method for examining target template strength: Pupillometry. Participants completed a relative-prevalence search task, wherein they searched for two target categories, butterflies and teddy bears. Although targets appeared in 50% of the trials, one category appeared in 5% of trials, and the other appeared in the remaining 45%. We used an RSVP paradigm to ensure that target objects were examined directly: Target objects were presented amid streams of rapidly presented pictures. After the stream concluded, participants indicated whether a picture from one of the target categories was present, or if both categories were absent. We tracked pupil dilation (a marker of memory strength and specificity) over three blocks of 100 trials. Across blocks, we observed a pupillary prevalence effect, wherein high-prevalence targets elicited greater pupil dilation, relative to low-prevalence targets. These findings suggest that high-prevalence targets resonate more strongly with mental representations of target templates used during search, and provide further evidence that low-prevalence targets are missed (at least in part) due to weaker templates, reducing "perceptual readiness" for their detection.

56.3024 Eye Movements Reveal the Competition between Basic and Configural Features in False Pop Out in Visual Search

Natalie Mestry[1](Natalie.Mestry@soton.ac.uk), Kimberley Orsten-Hooge[2], James Pomerantz[3], Nick Donnelly[1]; [1]Psychology, University of Southampton, [2]Psychology, University of Arizona, AZ, USA, [3]Psychology, Rice University, TX, USA

Pop out in visual search refers to quick and efficient identification of a target, e.g. a single, unique item among homogenous distractors. In false pop out (FPO, Orsten-Hooge, Portillo & Pomerantz, 2015), one of the homogenous distractors competes with the singleton target to pop out as it breaks a global pattern in the display. Behavioural responses have revealed FPO in both accuracy and RTs. Here, eye movements were used to further explore FPO. The task was always an odd-quadrant localization with three display types: FPO displays composed of negative and positive diagonal lines forming potential patterns being broken by one of the non-unique distractor lines; Line Control displays composed of horizontal and vertical lines forming no potential global pattern; and Letter Control displays composed of letter pairs (A/B, X/O) (Experiment 1; Orsten-Hooge et al., 2015). As predicted, FPO was found in both accuracy and RT measures with a 1000 ms display exposure duration (Experiment 1), but also with an unlimited display exposure duration (Experiment 2). Eye movements from Experiment 1 revealed participants made more fixations and had longer total fixation durations on FPO trials than on Line Control displays. Analysis of the eye movements from Experiment 2 showed participants made more fixations and fixation durations were longer during FPO display trials than with any Control display trial. During FPO display trials in Experiment 2, participants' attention was often drawn to the non-unique distractor item that broke the display's pattern. Importantly, this happened even when participants reported the unique item as being different. These results not only replicate initial findings regarding FPO (Orsten-Hooge et al., 2015), but also demonstrate the phenomenon via eye movements, lending strong support to the predication that FPO arises from competition between basic-feature and configural properties.

56.3025 Oculomotor Capture Despite Contextual Cueing in Scenes

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Abrupt onsets disrupt visual search with increased response times to the target as well as attentional capture of eye movements towards the irrelevant location. However, onsets may fail to capture attention when irrelevant to search or if a saccade has already been planned to another location. Contextual cueing in scenes has shown robust effects of explicit allocation to a target with faster search times and fewer eye movements. This study used a contextual cueing paradigm with repeated and novel search scenes. The final two search blocks introduced a 1o red square onset that appeared 100ms after central fixation or during a saccade landing more than 2o from center. The onset would appear 4o left or right of center on the same or opposite side of the target. Eye movements were monitored to determine whether an irrelevant onset would capture attention automatically despite knowledge of a target location from repeated scene contexts. Results showed both fixation and saccade onsets were highly significant compared to baseline measures of the area in previous blocks without the onset. A fixation onset on either side of the target within novel scenes was similar to onsets on the same side of a repeated scene target. However, a fixation onset on the opposite side of repeated scene targets was significantly different from the other fixation onsets suggesting less attentional capture when onsets are further from known target locations. Examination of ordinal fixations after fixation onsets showed significant proportions of looking by the first fixation for novel and repeated searches compared to baseline. Saccade onsets comparisons were not significantly different from baseline. Similar results across novel and repeated searches suggest memory for a known target location does not eliminate attentional capture of an irrelevant onset.

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56.3026 Losing track of your eyes while trying to find Waldo

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At VSS14, we reported an experiment where observers performed change detection with natural scenes. On 25% of trials, observers were asked to mark 12 locations where they thought they had searched in the last three seconds. Given the close relationship between fixation and attention, one might assume that they would know where they looked. However, observers subsequently viewed 10 more scenes and marked 12 locations where they thought a hypothetical observer would search in three seconds. Observers were no better at locating their own fixations than when they guessed someone else's, though in both cases, they were well above chance. Are observers bad at knowing their own fixations or good at guessing others' fixations? To test this, we replicated the experiment using artificial "Where's Waldo" scenes, since these make guessing others' eye-movements much harder. Participants previewed the Waldo display for 3 seconds. They were then given a non-Waldo search target, and searched the scene for another 3 seconds before making a target present/absent response. On 25% of trials, after the preview, there was no search. Observers were queried on where they had looked during preview. They were asked to place 12 clicks marking their fixations (3 seconds * 4 fixations/second). At the end of the experiment observers viewed 10 new Waldo displays and marked 12 locations where they thought someone else would have fixated. Here it seems much harder to guess where someone else will look and, indeed, performance was worse than in the previous experiment. Still, we found memory for one's own fixations (M=24%) was no more accurate than guesses about the fixations of a hypothetical observer (M=27%, p=.07) and performance was much worse than an ideal observer model (M=67%, $p < .001$). This replicates the previous experiment, suggesting that we have poor memory for where we just looked.

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56.3027 There and back again: Understanding the cause of revisits to distractors in high-prevalence visual searches

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In standard visual search tasks, targets appear on 50% of trials. This contrasts with real-world searches in which targets can be very rare indeed, such as airport screening. Previous work examining target prevalence (defined as the proportion of trials that contain a target) has found that, as prevalence increases, participants become increasingly likely to detect targets, while increasing their reaction times on target-absent trials. Eye-movement analyses have found that this pattern is not only due to an increase in the proportion of objects fixated as prevalence increases, but also to an increase in the likelihood that distractors will be revisited. Since search has a limited-capacity memory record for already-inspected objects, in the present study, we asked whether the increased revisitation rate in higher-prevalence searches results from memory capacity limitations, or from a tendency to revisit objects as prevalence increases. To address this, we engaged participants in a search for simple targets (T-shapes amongst L-shaped distractors) while tracking their eye-movements. Prevalence was set to 10%, 50% or 90%. We replicated standard prevalence effects: as prevalence increased, participants were more likely to detect targets. Revisitation rates also increased with prevalence. Across all prevalence levels, we found that participants were more likely to revisit objects that were first visited early in a trial, compared with objects first visited later in a trial: a finding consistent with a limited-capacity memory record. In addition to this rise in revisits for objects visited early during trials, we also found a general increase in revisitation rates for all objects as prevalence levels increased, regardless of when those objects were first visited. Our results suggest that the increased revisitation rates in higher-prevalence searches are not only caused by the limited-capacity memory for already-inspected objects. Rather, there is also tendency to revisit all objects as prevalence increases.

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56.3028 **Vanishing point facilitates target search in natural scenes**
ali borji[1](aliborji@gmail.com); [1]Computer Science Department, University of Wisconsin - Milwaukee, USA

To investigate whether vanishing point (VP) plays a role in gaze guidance during visual search, we asked 14 subjects (4 female, mean age=23.07, SD=1.26) to search for a target character (T or L) placed randomly on a 3x3 imaginary grid within an image (dva 37.6x24). Subjects reported their answers by pressing one of two arrow keys (left arrow for T). The scene remained visible until keypress for 10 seconds maximum. We measured subjects' reaction times (RT) and accuracies. Stimuli consisted of 270 color images (180 with a single VP, 90 without). The target happened with equal probability inside each cell (15 times L, 15 times T). Analyzing images with VP, we found that all subjects were significantly faster when the target happened inside the cell containing the VP, compared to cells without VP (median across 14 subjects 1.34 secs vs. 1.96; Wilcoxon rank-sum test; p=0.0014). Reaction time at VP cells was significantly lower than RT on images without VP (median 2.37; p=4.77e-05). Reaction time at off-VP cells (over images with VP) was lower than RT on images without VP (p=0.0072). This result was unexpected since we anticipated that VP would act as a distractor hence raising RT over off-VP cells. We attribute the higher RT for off-VP cells to lower complexity of scenes with VP as those scenes usually had relatively less clutter (Further, images without VP contained more face and text). Median (and mean) accuracies over subjects were above 95%. Accuracies for the target at VP cells were significantly higher than off-VP cells (medians 100% vs. 97%; p=0.02) and images without VP (median 95%; p=0.01). These findings support our previous results (Borji et al., arXiv 2015) that vanishing point, similar to face and text (Cerf et al., JOV 2009), attracts attention and gaze in free-viewing and visual search tasks.

56.3029 **Vanishing points attract eye movements during visual search**
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A vanishing point seems to be an important and convenient cue to understand visual scenes at a glance. It indicates depth, and the closer objects are, the smaller their sizes become. Considering that the resolution of our central vision is high whereas peripheral is low, seeing a vanishing point is efficient to perceive a whole scene. Borji et al. (2015) demonstrated that a vanishing point attracted visual attention in a free viewing task. Here, we examined whether vanishing points attract eye movements during visual search. In Experiment 1, we conducted a free viewing task using different natural scenes from the previous study and could replicate the effect of vanishing points. In Experiment 2, a Gabor patch was embedded in a natural scene, and participants were asked to search for it. The results showed that first saccade in each trial tended towards a vanishing point. To control for contrast and objects included in scenes, in Experiment 3 we investigated the effect of a vanishing point with simple geometric figures. In a half of pictures, lines converging to a vanishing point were invisible around the vanishing point, whereas in the other half, they were visible. Eight or twelve squares were presented and participants were asked to search for a rectangle among them. The results showed that vanishing points attracted attention even in scenes composed of simple geometric figures. In particular, the effect of vanishing points was larger than that of saliency when distance between a fixation point and a vanishing point was small. These results suggest that vanishing points attract attention during not only free-viewing but also visual search, and provide new insights into search models including saliency map.

Objects: Learning, top-down effects, unconscious processes

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

56.3030 **Base-Rate Sensitivity Through Implicit Learning**
Andrew Wismer[1](andrew.wismer@knights.ucf.edu), Urvashi Nayee[1], Christine Monir[1], Corey Bohil[1]; [1]University of Central Florida (Department of Psychology, College of Sciences)

Base-rate sensitivity is known to develop over time through direct experience in classification tasks without explicit presentation of frequency information. Sensitivity is commonly assumed to develop through implicit learning, and recent empirical work supports this claim (Bohil & Wismer, 2015). However, the relative contributions of implicit and explicit learning to base-rate sensitivity have yet to be addressed empirically. The goal of the present work was to dissociate the roles of the implicit and the explicit systems by using a factorial design that included both implicit and explicit learning disruptions. We tested the hypothesis that implicit learning underlies base-rate sensitivity from experience (and that explicit learning contributes little). Participants classified simple stimuli (bar graph heights) with a 3:1 base-rate ratio. Participants learned from either "observational" training known to disrupt implicit learning or from "response" training which supports implicit learning. Category label feedback was followed either immediately or after a 2.5 second delay by a working memory task designed to disrupt explicit reasoning about feedback. Decision criterion values were more conservative after observational training, suggesting that implicit learning underlies base-rate sensitivity. Disrupting explicit processing had no effect on base-rate learning as long as implicit learning was supported. A follow-up study that presented half of the participants with explicit base-rate frequency information (in place of the dual working memory task) again found more conservative decision criterion values when the implicit system was disrupted. Additionally, explicit base-rate information did little to promote a more liberal criterion. Taken together, these results suggest that base-rate sensitivity develops primarily through implicit learning, as predicted by the COVIS theory of categorization (Ashby et al., 1998).

56.3031 **Fleeting impressions of economic value via summary statistical representations**
Allison Yamanashi[1](ayleib@gmail.com), Kelly Chang[2], David Whitney [1]; [1]University of California Berkeley, [2]University of Washington

Glance at any supermarket or department store, and you will notice groups of products (stacks of produce, cans of food, racks of clothes etc). When customers view market displays, are they able to evaluate the price of the group as a whole? Or do they simply search through the crowd assessing the value of individual objects? Importantly, if observers were able to evaluate the ensemble price of a group of objects efficiently, this could be a useful function for strategic shopping, guiding search for particular objects, and for forming preferences. To test ensemble price sensitivity, twenty participants first estimated the prices of individual products from two major retailers. The results yielded high inter-rater reliability and high correlations with the retailers' listed prices. Next, we created groups of 6 objects (drawn from the rated products), and displayed these groups to new, independent participants for 1 second. Participants reported their perceived average price of each group. There was a high correlation between the average price based on single-product estimates (from independent observers) and the estimates of group price in the ensemble experiment. Our findings were robust across different displays (spatial and temporal groups) and across stimulus sets containing a variety of price ranges. Subjects integrated several objects into their ensemble price estimates, confirming that the visual impressions of value reflected a summary statistical representation. Interestingly, we also observed that ensemble coding biased participants' price evaluations: the perceived price of object groups was amplified compared to the average of the single items. Previous research investigated price evaluations when consumers are given time to cognitively deliberate about product value. The results here suggest that ensemble perception operates in a consumer's first glance and it can impact their initial impression of product displays.

56.3032 **Effects of scene consistency in subliminally perceived visual stimuli**
Jiyoon Stephanie Song[1](jiyoon_song@brown.edu), Hee Yeon Im[2], Christine Gamble[2], Joo-Hyun Song[2, 3]; [1]Department of Neuroscience, Brown University, Providence, RI, USA, [2]Department of Cognitive,

Linguistic and Psychological Sciences, Brown University, Providence, RI, USA, [3]Brown Institute for Brain Science, Brown University, Providence, RI, USA

Previous studies have shown that contextual consistency within a scene affects the accuracy of object recognition (Davenport & Potter 2004), but it is unclear how contextual consistency influences the perception of scenes that are viewed subconsciously. To address this question, we compared participants' responses to contextually consistent and inconsistent visual scenes in the presence of continuous flash suppression (CFS), which allows stimuli to be perceived without reaching conscious awareness. We created scene stimuli which we defined as contextually consistent if the foreground object corresponded to the background, and inconsistent if it did not. For each trial, CFS was presented at full contrast immediately to a randomly chosen eye, and a visual scene with a clear foreground object and background was gradually introduced to the other, non-suppressed eye. During each trial, participants indicated when the foreground object broke suppression and reached conscious awareness via key press, then verbally identified the foreground object. We defined reaction time (RT) as the time it took for participants to indicate via key press that the foreground object had broken suppression and entered conscious awareness. We also analyzed participants' accuracy in identifying the foreground object. In order to examine the relationship between scene context, perceptual awareness, and learning, participants were presented with the same set of visual stimuli twice, in two separate experimental blocks. For both the contextually consistent and inconsistent scenes, participants showed an improvement in object identification accuracy across blocks. Furthermore, when the scenes were contextually consistent, participants showed a decrease in RT across blocks in addition to the increase in object identification accuracy. Together, this suggests that the contextual consistency of scenes facilitates object recognition and learning, and that learning by means of repeated exposure can occur without conscious awareness of the stimuli.

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56.3033 Dichoptic Masking Interferes with Feedback to Early Visual Areas when Part- and Whole-Familiarity Conflict

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The perirhinal cortex (PRhC) is sensitive to the congruency of configuration familiarity and part familiarity; it modulates part-familiarity responses in early visual areas (EVA), facilitating them when familiar parts are arranged in familiar configurations (Fam-configurations), and inhibiting them when they are re-arranged into novel configurations (PR-configurations; Barense, et al, 2012). Whereas control participants reported seeing Fam-configurations as figures more often than matched PR-configurations, PRhC–damaged patients reported seeing the latter as figure just as often as the former. Without PRhC modulation their figure reports were based on part-familiarity alone. Using dichoptic masking, we interfered with visual processing in healthy participants and examined part- and configuration-familiarity based figure assignment. Three types of displays were shown for 40 ms, followed by a 40ms ISI, then by either a 20-ms or 200-ms mask: critical regions depicted Fam-configurations, PR-configurations, or control inverted PR-configurations (iPR-configurations). The different mask durations differentially affected figure reports for PR-configurations only. With the 200-ms mask, participants saw PR-configurations as figure as often as Fam-configurations and more often than iPR-configurations ($p < .05$). This is the pattern expected if the mask interfered with inhibitory feedback from the PRhC, leaving part-familiarity responses in the EVA intact. Thus, dichoptic masking can interfere with feedback from higher-level brain regions. With the 20-ms mask, the pattern of responses differed ($p< .01$): figure reports for PR-configurations did not exceed chance, whereas both Fam-configurations and iPR-configurations were seen as figure substantially more often (ps < .03), with the former greater than the latter ($p < .07$). Either the offset transient of the 20-ms mask or the 60-ms stimulus termination asynchrony (STA) interfered with part-familiarity responses in EVA. Consequently, noisy part-familiarity signals were sent forward. Results suggest inhibitory feedback reduces noisy signals more than facilitatory feedback enhances them. Future research will vary mask duration to elucidate these effects.

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56.3034 Top-down modulation of spatial frequency extraction

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According to prominent models of object recognition, the early extraction of low spatial frequencies (SF) modulates in a top-down fashion the later extraction of high SFs. In the present study, we investigated the precise time course of SF extraction during object recognition in 49 healthy adults. On each trial, a short video (333 ms), in which the SFs of an object were randomly sampled across time, was presented. An object name followed and subjects had to indicate if it matched the object. We then performed multiple linear regressions between SF x time sampling planes and accuracy. We observed a continuous extraction of low SFs (1-21.5 cycles per image, cpi) with an extraction of higher SFs (up to 36 cpi) afterwards ($t > 4.00$, $p < .05$). This means that some information was extracted at specific moments regardless of what was seen before (i.e., ballistically). Next, we performed the regressions after having weighted trials according to the quantity of low SFs (1-20 cpi) shown in the first 167 ms. We observed that high SFs (up to 35 cpi), but also lower SFs (as low as 3 cpi), led to more accurate responses when they were preceded by low SFs ($t > 3.78$, $p < .05$). These results indicate that SF extraction is modulated by the earlier extraction of low SFs (i.e., adaptively). To disentangle adaptive and ballistic aspects of visual processing, we analyzed the modulation of SFs in every frame by low SFs in every preceding frame. Information around 150-242 ms was exclusively modulated by low SFs around 80-96 ms ($t > 3.96$, $p < .05$). Altogether, these results suggest a top-down modulation of SF extraction, but not limited to high SFs, and occurring at specific moments.

56.3035 Sensitivity to statistical covariation of visual features is feature-specific

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In the real world, we face a constant flow of visual features. Our visual system has to cope with it, but its capacity is too limited to grasp all the visual features at a glance. Fortunately, information in the real world is often redundant. Aggregating inherent property of visual features as its statistical summary would therefore be efficient in representing the complex real world. Many studies suggest that we are able to extract some statistical summary, such as mean, variance, etc. from a single visual feature under brief viewing. It is also likely that we could extract covariation, a statistical description on multiple features, which would also greatly help to form a compact representation of the visual world. We examined the human sensitivity to the statistical covariation embedded in a visual scene display consisting of several circles filled with a sinusoidal grating. Different circles had different sizes and sinusoidal orientations, which assigned three types of covariation between features: size-orientation, orientation-location, and size-location. The degree of covariation was manipulated by varying the Pearson correlation coefficient. Participants sequentially viewed two 250-ms displays, and then judged which display contained the more correlated features. One display had a perfect correlation ($r = 1.0$) and the other not ($r = 0$, 0.33, or 0.67). Our results showed that the correct response performance was significantly lower for the size-orientation combination (slightly above chance level) than those for the other two location-related combinations. This was robust for various experimental conditions, namely varying ranges of stimulus values, reversing the direction of correlation, and reducing the top-down task set: All showed robustness for the lower performance for size-orientation and higher one for location-related correlation judgments. This suggests that, under brief viewing, human perception of statistical covariation among multiple features is founded on location dimension.

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56.3036 Adaptation of numerical magnitude by visual size

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Recent psychophysical and electrophysiological work in various species suggest the existence of a number sense. Parietal areas in the brain contain neurons specialized for processing the numerosity of elements in the visual scene. Here, I used the technique of size adaptation to investigate its influence on number, size and density judgements of random dot numerosity patches. Size adaptation only changes the apparent, not the physical size of the probe patch, thereby avoiding confounds with changes in physical dot density. The effect of size adaptation on number judgements depended on the numerosity of elements in the probe stimulus: Adaptation magnitude increased logarithmically with numerosity in the probe patch. Judgements of dot density however were unaffected by size adaptation. Effects on size estimations remained constant across the tested numerosities and thus cannot explain the logarithmic effects on number estimations. Since judgements of low number were not affected by modulations of apparent size, it is likely that they are sensed directly, irrespective of low-level features as size and density. However, the influence of low-level features increased as a function of the amount of dots presented in the probe patch. I also measured the spatial spread of number adaptation for low numerosities. The broad spread of adaptation is consistent with processing of number neurons which have large receptive fields. These results suggest the existence of a number sense for low numerosities and a mechanism for high numerosities, which integrates features as size and density.

56.3037 **Factors affecting the perceived genuineness of security documents** Osamu Masuda[1, 2](osamu-masuda@nuhw.ac.jp), Marius Pedersen[2], Jon Hardeberg[2]; [1]Niigata University of Health and Welfare, [2]Gjøvik University College

The values of security documents such as banknotes depend on the subjective confidence in those security documents by their users. We tried to elucidate what factors are affecting the perceived genuineness of security documents. In the first experiment, we investigated how people's awareness to security features influences the perceived resistance of banknotes against counterfeiting. Nine banknotes actually circulated on the market were sampled and presented to sixteen observers. The observers reported as many security features found on each banknote as possible and ranked the perceived resistance of those banknotes against counterfeiting. The interval scale of perceived resistance was estimated from the rank order data. A highly significant correlation between the perceived resistance against counterfeiting and the average number of security features found by the observers on each banknote, but no correlations were found with other metrics. This suggests that security features on security documents should be designed self-explanatory. In the second experiment, we tried to investigate what factors of the portraits in banknotes are affecting the perceived genuineness of the banknotes. Each of seventeen banknotes was enclosed in an envelope with a hole so that only the portrait area was presented to twenty-one observers. The observers judged the genuineness of each portrait as a part of a banknote according to a 5-category Likert scale. At the same time, observers reported the criteria in rating the genuineness of banknotes and features mentioned by the observers were recorded during the sessions. The interval scales of the genuineness of the banknotes judged from their portraits were constructed with Torgerson's law of category judgement. By comparing highly-rated notes in genuineness with lowly-rated notes, it was suggested that the lack of complexity in design makes banknotes look less genuine and that reasonable and plausible wear and tear make banknotes look more genuine.

56.3038 **The role of duration in the experience of beauty** Lauren Vale[1](lauren.vale@nyu.edu), Denis Pelli[1]; [1]Psychology Dept., New York University

Imagine catching a glimpse of Monet's Water Lilies in an art museum. How long must one look at an image to experience beauty? We examined how exposure duration affects the experience of beauty. Before the experiment, we asked participants to, "pick images that are movingly beautiful to you" from Google images. We also selected moderately rated non-beautiful IAPS images, which will be referred to as "pretty". We measured pleasure continuously (using emotiontracker.com) until 30 s after a variable-length presentation (1 to 30 s) of a beautiful or pretty image. At the end of each trial we asked participants if they felt beauty (yes or no). We fit the pleasure ratings after stimulus offset with an exponential decay $\alpha \cdot \exp(-t/\tau)$ with two parameters: amplitude α and time constant τ. Pleasure ratings were lower for pretty (M±SE=5.4±0.6) than for beautiful (7.8±0.8) images. For beautiful images, increasing exposure duration (1, 6, 15, or 30 s) hardly changed the frequency of reporting feeling beauty at the end of the trial (P = 58%, 56%, 57%, and 63%; SE=5%), but produced higher pleasure (α = 6.0, 5.9, 6.7, or 7.3; SE=0.6), which decayed more slowly (τ = 0±57, 20±33, 133±71, 381±190). Thus, we found that a beautiful image produces more pleasure than pretty images, and the pleasure felt after 30 s exposure to a beautiful image lingers twice as long as that from shorter durations (1, 6, or 15 s).

56.3039 **Compensation for blur requires an increase in field of view** MiYoung Kwon[1](miyoungkwon02@gmail.com), Rong Liu[1]; [1]Department of Ophthalmology, School of Medicine, University of Alabama at Birmingham

Spatial resolution is an important factor in human pattern recognition. In particular, low resolution (blur) is a defining characteristic of low vision. Blur changes image information such that fine local information is largely reduced while global or configural information (i.e., the spatial interrelationship between local features) is likely to remain intact. A possible interaction between blur and field of view comes from an interesting observation that a larger field of view is advantageous to access configural information of an object. Here, we investigated an interaction between the two by assessing field of view requirement for blurry object recognition. Eight normally-sighted subjects were asked to recognize letters and faces blurred with a low-pass filter (cycles/object cutoff) using a moving-window paradigm. Subjects viewed an object of fixed size through a gaze-contingent viewing window with varying sizes until they recognize it. Field of view requirement, quantified as the total number of "views" (i.e. repositions of the window) required for correct recognition, was obtained for three blur levels. Number of views increased as the window size decreased. More importantly, the increase in the number of views was more pronounced with increasing blur level ($F(2, 98) = 21.66$, $p < 0.001$ for letter; $F(2, 98) = 12.63$, $p < 0.001$ for face), suggesting that a larger field of view is required to recognize blurry objects of a given size. Our findings suggest that, while human observers excel at recognizing severely blurred objects, compensating for blur requires an increase in field of view, which may challenge object recognition in low vision. Thus, the interaction between blur and field of view should be considered when low vision rehabilitation or assistive aids are designed.

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Motion: Neural mechanisms

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

56.3040 **Cortical responses to moderate- and high-speed gratings extending 60° in the peripheral visual field** Kyriaki Mikellidou[1](kmikellidou@gmail.com), Francesca Frijia[2], Domenico Montanaro[2], Vincenzo Greco[3], David Burr[4,5], Maria Morrone[1,6]; [1]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Italy, [2]Fondazione CNR/Regione Toscana G. Monasterio, Pisa,Italy, [3]Istituto Nazionale di Ottica, CNR Florence, Italy, [4]Department of Neuroscience, Psychology, Pharmacology and Child Health, University of Florence, Italy, [5]Neuroscience Institute, CNR, Pisa, Italy, [6]Stella Maris Scientific Institute, Pisa, Italy

We investigated the BOLD response to motion presented to large visual fields. We stimulated the visual cortex using moderate (0.26 c/deg, contrast 50%, 38 deg/sec) and high speed (0.018 c/deg, contrast 50%, 571 deg/sec) drifting gratings, projected to a large field of view (~60°). These stimuli had the same contrast envelope (50%) and temporal frequency (10 Hz), and very similar contrast sensitivity (~500) at all eccentricities. Stimuli differed only in spatial frequency, and hence speed (by a factor of 14). We measured BOLD responses to these stimuli in various subcortical and cortical visual areas with a GE 3T scanner (Excite HDx, GE Medical Systems, Milwaukee, WI), using a block design. Stimuli were presented with a novel optical setup capable of projecting wide-field images at 120 Hz. Retinotopic maps for ten healthy volunteers were constructed using (i) horizontal and vertical meridian stimulation, (ii) upper, lower, left and right stimulation of the four visual quadrants and (iii) checkerboard stimuli to map eccentricity. Stimuli were viewed monocularly (right eye). Despite the 14-fold difference in spatial frequency and speed, causing very different stimulation of magno and parvo cells, responses in both the lateral geniculate nuclei and the superior colliculi were similar to the two stimuli. In several cortical areas, including V1 (except the far periphery), V3, V3ab, LOC, hMT+, V6 and V7, the BOLD response was the same to both stimulus speeds. However, there was a distinct preference to moderate-speed gratings in areas of the ventral stream, V2 and V4. And in the extreme periphery of V1, and possibly an adjacent area not previously mapped (that could correspond to the monkey prostriata), there was a clear preference for fast-moving gratings. This points to different selectivity for speed in the dorsal and ventral streams, after primary visual cortex.

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56.3041 **Primary visual cortex and behavioral responses to reverse-phi motion in mice.** Laurens Kirkels[1](l.kirkels@donders.ru.nl), Jacob Duijnhouwer[2], Wenjun Zhang[1], Martha Havenith[1,3], Jeffrey Glennon[3], Richard Wezel[1,4]; [1]Department of Biophysics, Donders Institute for Brain, Cognition and Behavior, Radboud University Nijmegen, The Netherlands, [2]Center for Molecular and Behavioral Neuroscience, Rutgers University, Newark, Newark, NJ 07102, USA, [3]Department of Cognitive Neuroscience, Donders Institute for Brain, Cognition and Behavior, Radboud University Nijmegen, The Netherlands, [4]Biomedical Signals and Systems, MIRA, Twente University, The Netherlands

Tuesday PM

When the contrast of a moving random dot pattern is flipped periodically, the direction of motion appears reversed. This phenomenon is called reverse-phi motion. In this study we tested whether mice are susceptible to this effect. We measured neural activity in primary visual cortex (V1) and optomotor reflex behavior in response to reverse-phi motion. Our visual stimuli consisted of randomly positioned black and white dots that we moved using a single-step dot lifetime paradigm. The luminance contrast of the dots was constant ('phi motion') or inverted each step ('reverse-phi motion'). We used two-photon calcium imaging to measure the neural responses of layer 2/3 V1 neurons of awake mice that passively viewed the moving dots on a screen. In the behavioral experiments, we projected the moving dots on the inside of a dome that covered the entire visual field. We measured the spontaneous optomotor reflexes that this motion elicited in head-fixed mice that ran on a spherical treadmill. We found that direction-tuned V1 neurons systematically reversed their tuning to phi and reverse-phi motion. The behavioral tests show that running mice turned in response to our stimuli in a manner consistent with the phi and reverse-phi motion percepts. Our findings suggest that mice perceive reverse-phi motion and that this is reflected in neural responses at the level of V1.

Acknowledgement: NWO-MagW

56.3042 **Perceptual training alters residual motion processing in V1-damaged humans** Michael Melnick[1](mmelnick@mail.cvs.rochester.edu), Matthew Cavanaugh[2], Marisa Carrasco[3], Duje Tadin[1,2], Krystel Huxlin[1,2]; [1]Department of Brain & Cognitive Sciences, University of Rochester, Rochester, NY, USA, [2]Flaum Eye Institute, University of Rochester Medical Center, Rochester, NY, USA, [3]Department of Psychology, Center for Neural Science, New York University, New York, NY, USA

Stroke-induced damage to primary visual cortex causes loss of conscious vision in the contralateral hemifield. Global motion discrimination training can partially reverse this cortical blindness (CB) at trained locations, recovering near-normal coarse direction discrimination, but leaving fine discrimination impaired. Here, we examined several possible mechanisms for this partial recovery. We used random dot stimuli (10°/s, 3 dots/deg2) containing a Gaussian-distributed range of dot directions centered on the signal direction (Figure 1B), to measure tuning functions for direction in 7 CB subjects. Subjects judged whether dots moved above or below the left/rightward direction (Figure 1A), with thresholds defined as the direction difference resulting in 82% correct performance. Measures were collected before and after left-right direction discrimination training in the blind field and at corresponding intact field locations. Gaussian functions were fit to generate tuning curves for motion channel sensitivity to increased dot direction range (Figure 2). Where measureable (n=5), individual tuning curves were significantly wider at retrained, blind field locations than in the intact hemifield, suggesting broader population tuning to motion in retrained locations. In addition, a neurally plausible generative model of motion discrimination was then utilized to determine if model neurons with broader motion tuning would produce similar psychophysical performance as retrained CB patients. Using a bank of MT-like motion detectors, the model suggests that the source of deficits in fine direction discrimination may be a sparser neuronal population and lower firing rates. Overall, these data suggest that performance in retrained CB fields results from a combination of altered tuning and weaker, sparser neural responses. Thus, an additional, fundamental limit to complete recovery in CB fields may be the number of motion selective neurons available for signal processing, particularly in fine difference tasks of this type.

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56.3043 **Changes in visual motion processing by neurons in mature primary visual cortex (V1) following early color deprivation** Heywood Petry[1](woody.petry@louisville.edu), Wenhao Dang[1], Elizabeth Johnson[2,3], Stephen Van Hooser[4]; [1]Dept. of Psychological & Brain Sciences, University of Louisville, [2]Dept. of Neurobiology, Duke University School of Medicine, [3]Duke Institute for Brain Sciences, Duke University, [4]Dept. of Biology, Brandeis University

Tree shrews (Tupaia) possess dichromatic color vision based on short wavelength sensitive (SWS) and long wavelength sensitive (LWS) cones. Deep red-light-rearing (RLR) selectively deprives SWS cones, and produces differential stimulation of color and luminance pathways. After months of subsequent housing in white light, RLR shrews show poorer color discrimination (Petry & Kelly 1991) coupled with enhanced high temporal frequency vision (Callahan & Petry 1995). Retinal ganglion cells of RLR shrews also are tuned to higher temporal frequencies (Lu & Petry, 2002) indicating an initial retinal locus. To address how this atypical high frequency information is processed and represented in V1, where many signals have been shown to correlate with perception, we compare two-photon imaging with single-unit recordings of receptive field properties. Normally-reared tree shrews and RLR tree shrews (reared from birth to 8-wks of age in deep red light then housed in standard white light) were studied. Two-photon calcium imaging: the fluorescence of identified cells in V1 layers II/III was computed in response to achromatic 0.2-0.4 c/deg sine-wave gratings drifting at 0.5-32Hz. Extracellular recordings were obtained using tungsten microelectrodes from single neurons in V1 layers II/III, IV and V. Flashing Gaussian spots, drifting achromatic sine-wave gratings, random-dot kinematograms, and sparse noise stimuli were used. Taken together, results of the imaging and single-unit recordings revealed V1 neurons in RLR shrews that exhibited higher, and lower, temporal frequency preferences than controls. Furthermore, RLR changed the stimulus selectivity profile of layer IV neurons. This suggests that temporal filtering mechanisms in cortex are susceptible to modification during early post-natal development by other inputs (e.g., color pathways), likely by competitive interactions at earlier levels of processing. These findings strengthen the evidence for an enhancement of temporal vision (paired with deficit in color vision) in RLR shrews that can be perceived and used in their behavior.

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56.3044 **The fast and the curious: A velocity code model based on MT pattern and component neurons can explain why a moving grating plus a plaid (V + .5V) looks faster than just two gratings (also V + .5V).** John Perrone[1](jpnz@waikato.ac.nz); [1]School of Psychology, The University of Waikato, Hamilton, New Zealand

I have proposed a model of how the primate visual system extracts a speed signal from the activity of a small set of Middle Temporal (MT/V5) neurons (Perrone, JOV, 2012). I suggest that the visual system uses the activity from a number of velocity channels each made up of a 'triad' of MT neurons tuned to 2V, V, .5V and spatial frequencies (u/2, u, u). A unique aspect of the model is that the .5V unit is a component type neuron whereas the other two are pattern types. For a compound, horizontally moving stimulus made up of two sine wave gratings (sf1 = sf2 = u) with speeds V and .5V, the model speed output is given by the weighted vector average of the MT triad activity (0 x 2V, 1 x V, 1 x .5V) = .75V'. The 2V unit is inactive because it is tuned to speed 2V and sf = u/2. If we now replace the .5V grating with a 150° plaid (overall speed = .5V) the activity distribution is (0 x 2V, 1 x V, 0 x 5V) with predicted perceived speed = V' because the plaid does not activate the .5V MT component unit. The ratio of the perceived speeds (Rpg) for the two types of compound stimuli (with plaid/with grating) should therefore be 1.33 (1/.75). This prediction was tested using a psychophysical procedure with the speed of the two types of compound stimuli compared against a single variable grating. The mean Rpg value from 3 observers was 1.32 (95% CI = 1.28 – 1.37). This supports the idea that speed estimation involves an MT component neuron and challenges velocity population code models based on a winner-takes-all mechanism or models that do not distinguish between a .5V grating and plaid (both types predict Rpg = 1.0).

56.3045 **MT neurons are less directional selective after chronic V1 lesions in adult marmoset monkeys** Leo Lui[1,2,3](leo.lui@monash.edu), Maureen Hagan[1,2], Tristan Chaplin[1,2,3], Krystel Huxlin[4]; [1]Neuroscience Biomedical Discovery Institute, Monash University, Australia., [2]Department of Physiology, Monash University, Australia., [3]Australian Research Council Centre of Excellence for Integrative Brain Function., [4]Flaum Eye Institute, University of Rochester, Rochester, NY, USA.

The Middle Temporal Area (MT), an area important for motion perception in primates, receives most of its inputs from the Primary Visual Cortex (V1). However, in primates, MT cells continue to respond to motion stimuli presented in the scotoma 1-3 months after lesions (Rodman et al. 1989 in macaques; Rosa et al. 2000 in marmosets). Here, we further quantify these responses to determine if they are maintained chronically (>6 months) after permanent V1 damage. Maintained responsiveness in MT and corresponding dorsal stream areas has been reported to underlie visual sensations, including blindsight, after V1 lesions in monkeys and humans (Cowey 2010; Leopold 2012). We recorded from MT cells in two anesthetized adult marmosets 10-11 months following partial, unilateral V1 lesions (central 20-40 degrees). Location of each scotoma was determined by V1 recordings around the lesion border. For MT recordings, random dot motion stimuli were presented within circular apertures that approximated the neurons' receptive fields. For each cell, we computed a discrimination index (DI) based on its response to eight directions of motion (Uka and DeAngelis 2003). Sixty-six units (46 from monkey 1, 20 from monkey 2) responded to these stimuli. While directionally selective responses were found inside the scotoma, DI was significantly reduced compared 25 MT cells from two intact animals. The proportion of directionally selective cells was also reduced (54% in monkey 1, 20% in monkey 2; normal >90%). Thus, marmosets, just like old world primates, exhibit preservation of directional responses in MT after V1 lesions, but direction selectivity is decreased. This may be explained by a shift in the balance of MT's inputs towards sub-cortical regions, whose cells tend to be less directional than V1 neurons in intact animals. Decreased direction selectivity may also represent a significant constraint to restoring completely normal motion perception in chronic V1-damaged patients.

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56.3046 **Format-independent cortical representations of interactive events** Alon Hafri[1](ahafri@sas.upenn.edu), John Trueswell[1], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania

The social world can be understood in terms of interactive events: people do things to one another and outside forces act upon them. These events can be classified into categories (kicking, brushing) that abstract away from inessential particulars such as the setting, identities of the actors, and perceptual details. What are the neural systems that support visual event categorization? To address this question, we used fMRI to identify brain regions that represent event categories in a format-independent way. We scanned participants while they viewed two-participant interactions (slap, kick, shove, bite, pull, brush, massage, tap) and performed an orthogonal 1-back task. Crucially, we included two stimulus formats, in separate runs: (1) carefully controlled videos of actors performing these events; and (2) visually varied photographs of these events, which were selected from Google Image to maximize visually dissimilarity amongst exemplars within each category (as assessed by hue, saturation, and value features, and GIST model features). Thus we were able to investigate neural representations of event categories both within- and across-format. Within the video format, a searchlight analysis of multivoxel patterns revealed widespread decodability of event category (e.g. kick) across occipital, parietal, and temporal cortex, and included regions known to respond to visual features relevant for distinguishing actions, such as the extrastriate body area, hMT+, and biological motion areas in the superior temporal sulcus. Within the image format, event category was decodable in a smaller set of brain loci, including bilateral supramarginal gyri and right posterior middle temporal gyrus. Notably, cross-format decoding was largely restricted to these same loci. Furthermore, the similarity structure among event category representations in these regions was reliably consistent across subjects. We propose that these brain regions constitute a link between visual recognition systems and conceptual systems that allow flexible, complex thought about who did what to whom.

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56.3047 **Theta-burst rTMS to the right superior temporal sulcus impairs emotion recognition from biological motion** Rochelle Basil[1](rsceats@masonlive.gmu.edu), Margaret Westwater[2], Martin Wiener[1], James Thompson[1]; [1]George Mason University, [2]Cambridge University

Understanding the emotions of others through nonverbal means is critical for successful social interactions. Social communication hinges upon the ability to read and respond appropriately to the bodily kinematics of others. Although healthy individuals recognize emotions from sparse point light displays (PLDs) of body movements, individuals suffering with neurocognitive disorders like schizophrenia and Autism Spectrum Disorder show impairment in such recognition. Research has implicated the right superior temporal sulcus (rSTS) as a cortical region involved in the perception of biological motion. In the present study, we temporarily disrupted neural activity of the rSTS by using continuous theta-burst repetitive transcranial magnetic stimulation (rTMS) to examine whether the rSTS plays a causal role in the recognition of emotions from biological motion. Participants (N= 23; 13 females) completed two rTMS sessions in which we assessed the accuracy and reaction time (RT) of emotion recognition (angry, happy, fearful) from biological motion stimuli, as well as non-biological motion recognition using a global motion control task. We applied rTMS for 41 seconds on two separate cortical regions: (1) the rSTS, individually localized through fMRI using a comparison of intact versus scrambled biological motion stimuli and (2) vertex. Accuracy and RT were assessed before and after rTMS. Using repeated measures ANOVA, we found an interaction between rTMS site and stimulus type ($p < 0.05$), reflecting reduced accuracy of emotion recognition from biological motion following rTMS to rSTS but not vertex while accuracy in the global motion control condition did not differ across sites. Effects of rTMS on reaction time were not significant ($p>0.1$). These data support the causal role of the rSTS in decoding information about other's emotional state from their body movements. These effects were not due to an overall global motion deficit.

56.3048 **Opposed effects of high- vs. low-frequency transcranial random noise stimulation on visual motion adaptation** Gianluca Campana[1,2](gianluca.campana@unipd.it), Rebecca Camilleri[1], Beatrice Moret[1], Andrea Pavan[3]; [1]Department of General Psychology, University of Padova, Italy, [2]Human Inspired Technology Research Centre, University of Padova, Italy, [3]School of Psychology, University of Lincoln, UK

Transcranial random noise stimulation (tRNS) is a recent neuro-modulation technique whose effects at both behavioural and neural level are still debated. Here we exploited the well-known phenomenon of motion aftereffect (MAE) in order to investigate the effects of high- vs. low-frequency tRNS on motion adaptation and recovery. Participants were asked to evaluate MAE duration following the exposure of a circular rotating and expanding grating for 30 s, while being stimulated with either sham or tRNS across different blocks. Different groups were administered with either high- or low-frequency tRNS. Stimulation sites were either bilateral hMT+, early visual areas or frontal areas. Results showed that, whereas no effects on MAE duration were produced by stimulation of early visual areas or frontal areas, high-frequency tRNS caused a significant decrease in MAE duration whereas low-frequency tRNS caused a significant corresponding increase in MAE duration. These data indicate that high- vs. low-frequency tRNS has opposed effects on the unbalance, created by adaptation, between neurons tuned to opposite motion directions, and thus on neuronal excitability

56.3049 **Visual motion serves but is not under the purview of the dorsal pathway** Sharon Gilaie-Dotan[1](shagido@gmail.com); [1]ICN, UCL

Visual motion processing is often attributed to the dorsal visual pathway despite visual motion's involvement in almost all visual functions. Furthermore, some visual motion tasks critically depend on the structural integrity of regions outside the dorsal pathway. Here, based on our findings and numerous additional studies in human and non-human primates, I propose that visual motion signals are swiftly transmitted via multiple non-hierarchical routes to motion-dedicated processing regions (MT/V5 and MST) and then propagated to a multiplicity of brain areas according to task demands, reaching these regions earlier than the hierarchical flow. This not only places MT/V5 at the same or even earlier visual processing stage as that of V1, but can also elucidate many findings with implications to visual awareness. While the integrity of the non-hierarchical motion pathway is necessary for all visual motion perception, it is insufficient on its own, and the transfer of visual motion signals to additional brain areas is crucial to allow the different motion perception tasks (e.g. optic flow, visuo-vestibular balance, movement observation, action execution, dynamic form detection and perception, and even reading). Multiple provided predictions allow testing this proposal.

Multisensory Processing: Vision, touch and balance

Tuesday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4001 **Alpha oscillations and desynchronizations facilitate visual-tactile multisensory integration** Lei Ai[1](lai@gradcenter.cuny.edu), Tony Ro[1]; [1]The Graduate Center, The City University of New York

Recent studies have shown that neural oscillations in the alpha band (approximately 7-13 Hz) are involved in visual as well as touch perception, but the role of alpha oscillatory activity in visual-tactile multisensory integration is not very well understood. In this study, we recorded scalp electroencephalographic (EEG) activity to assess how alpha oscillations may affect the temporal dynamics of visual-tactile integration. Near-threshold tactile stimuli and suprathreshold visual stimuli (i.e., LED flashes) were delivered on the left middle finger at stimulus onset asynchronies (SOAs) that ranged from -200 ms (vision first) to 200 ms (touch first) in steps of 50 ms. Compared to the touch-only condition, tactile detection rates were significantly higher if the visual stimulus occurred between -150 ms and 100 ms of the tactile stimulus. In correspondence with these psychophysical data, changes in alpha power were measured across vision first SOAs, with a negative correlation between pre-touch alpha power and touch detection rate. Furthermore, inter-trial phase coherence spiked shortly after the visual stimulus, indicating that the phase of alpha oscillations was also reset by

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vision. Bootstrap analyses confirmed these phase resets by showing inversions of phase angle polarity that followed an alpha cycle. Unlike previous results showing an alpha phase-dependent effect on detection, however, detection rates were increased at all alpha phases, likely due to the desynchronization/decrease in alpha power. Similarly, when a tactile stimulus was delivered within 100 ms prior to a visual stimulus, detection rates and the P300 event-related potential to the tactile stimulus were also enhanced, likely from alpha power decreases that were induced by the subsequent visual stimulus. These findings suggest that alpha amplitude and phase modulations induced from a visual stimulus may enhance the processing of a tactile stimulus when it is delivered in close temporal proximity.

Acknowledgement: NSF

56.4002 Effect of prior knowledge on visual localization of tactile stimulation

Stephanie Badde[1](stephanie.badde@nyu.edu), Hyunjin Oh[1], Michael Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

The ability to localize tactile stimuli on the skin varies with stimulus properties (e.g., strength). We tested whether humans systematically incorporate stimulus properties and prior knowledge when localizing tactile stimuli relative to a visual reference. On each trial, a stimulator in one of five horizontally aligned locations (10 mm spacing) gently buzzed the back of the right hand. Stimulators were hidden from view by a white foam block. Participants fixated a mark projected onto the block (horizontally centered on the right hand, vertically aligned with the stimulators). Consequently, participants received constant visual feedback about the hand's position and shape, features typically misestimated in the absence of vision. After each tactile stimulus a different "ruler" (horizontal row of 5 mm wide colored patterns) was projected onto the block at the height of the stimulators. Participants indicated the perceived location of the stimulus by selecting a pattern. We are interested in localization bias, so no feedback was given. In separate sessions, the stimulator locations were distributed around the center, left or right side of the hand; the fixation mark was always projected on the center of the hand. In two practice blocks, the session-specific spatial distribution of stimulation was learned at the beginning of each session. Two strengths of vibrotactile stimulation were used, chosen randomly. Participants showed a localization bias towards the center of the locations tested in each session. This bias was much stronger for the weaker stimulus strength. There was an additional bias toward the center of the hand (i.e., the fixation mark). Performance was consistent with a Bayesian model of localization combining a prior expectation based on the distribution of stimuli in a session with a likelihood whose variance depended on stimulus strength as well as a bias towards center of the hand (visual fixation).

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56.4003 Integration of somatosensory and proprioceptive sensation in the localization of touch in visual space

Michael Landy[1,2](landy@nyu.edu), Aotian Yang[1], Stephanie Badde[1]; [1]Dept. of Psychology, New York University, [2]Center for Neural Science, New York University

Tactile stimuli are initially represented with respect to their location on the skin. However, to direct gaze towards the source of a tactile stimulus, its location in external visual space must be determined. That is, body posture has to be taken into account to enable tactile-visual interaction. The ideal observer derives the external location of a tactile stimulus as the vector sum of the location of the touch on the hand and the location of the hand in space. To determine whether humans apply this ideal strategy, participants performed three tasks: 1) Somatic: localization of a tactile stimulus on the hand, 2) Proprioceptive: localization of the hand in space, and 3) Cue integration: localization of a tactile stimulus in space. Somatic stimulation was a gentle buzz in one of 9 locations on the back of the hand. For each stimulus, the hand was passively moved to a new location under computer control. Participants indicated which of two sequentially presented locations (a standard and a comparison, in random order) was further to the right (2IFC, with feedback). For the standard, the hand was centered and the tactile stimulus, if any, was the central buzzer location. For the comparison, hand and/or buzz locations varied randomly over trials. Test locations were 6-24 mm left or right of the standard. In the cue-integration task, a factorial combination of hand and buzz location was used. JNDs in the cue-integration task were slightly worse than predicted from the two single-cue tasks. Analysis of PSEs in the cue-integration task suggests that participants weighted the cues unequally in the vector sum, even though this strategy is disadvantageous. Our results provide the first formal evidence that somatic and proprioceptive cues are combined incorrectly for estimating tactile location in visual space, which is the basis of tactile-visual interaction.

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56.4004 Interplay between visuo-tactile interactions and attentional control over perceptual selection

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Apparent motion is an illusion in which static objects are perceived to be in motion when presented in quick succession. We investigated the interplay between cross-modal interactions of visual and tactile stimuli and attentional control over perceptual selection. We used a novel paradigm that combined apparent motion synchronously presented in both visual and tactile domains. As visual stimuli we used ambiguous motion quartets where the probabilities of horizontal and vertical percepts are equal. The tactile illusion of apparent motion was created using pairs of vibrotactile signals produced by a stimulation array of four solenoid tappers attached to the palmar surface of the upper and lower phalanxes of the middle and index fingers of the left hand. Ten subjects participated in two experiments. In Experiment 1, only visual stimuli were presented continuously in the peripheral visual field (15° from the fixation dot) and participants were instructed either to (a) passively report their percept of the apparent motion, (b) switch the direction of motion as quickly as possible, (c) hold the current motion direction as long as possible. The phase durations of the hold and switch conditions were significantly longer and shorter, respectively, than the phase durations of the passive condition. This demonstrates the ability of participants to select and attentively hold one of the alternating visual percepts. In Experiment 2, the visual stimuli were rhythmically synchronous with apparent tactile motion and the observers still had to report their perception under the three different instructions. The participants could hold the horizontal percept for significantly longer periods when the visual stimuli were presented in combination with synchronous congruent tactile stimuli. The experiments demonstrate that combinations of rhythmically synchronous visual and tactile stimuli enhance healthy observers' attentional control over what they perceive.

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56.4005 Early experience alters the developmental trajectory of visual, auditory and tactile sound-shape correspondences

Hiu Mei Chow[1](dorischm@gmail.com), Daniel Harris[1], Sandy Eid[1], Vivian Ciaramitaro[1]; [1]Psychology Department, College of Liberal Arts, University of Massachusetts Bboston

Crossmodal correspondence, the association of information across the senses, is an ubiquitous multisensory phenomenon. The bouba/kiki effect, a prime example, finds an association between an abstract shape, spikey or round, and a nonsense word, /kiki/ or /baba/, respectively. This effect is found across cultures and languages, early in development, and is manifest in different senses (see Spence, 2011, for a review). Little is known of how development and experience alter this correspondence. Here we examine if the association strength of the bouba/kiki effect is modulated by age and experience. Over 400 participants, 3-80 years old, were recruited from the Museum of Science Boston. Participants chose (1) which of two visual shapes best matched a given non-sense word (Experiment1: sound-to-visual-shape), (2) which of two sounds best matched a given visual shape (Experiment2: visual-shape-to-sound), or (3) which of two felt shapes, hidden-from-view, best matched a given non-sense word (Experiment3: sound-to-tactile-shape). We quantified association strength by measuring the proportion of trials a round attribute (e.g. round visual/tactile shape or an /a/ sound) was chosen for each stimulus type over multiple repeats of each stimulus combination. We found that association strength increased during early and middle childhood, plateaued before adulthood, and declined in older adulthood. Across experiments, association strength was modulated by musical and language experience, with a trend of enhanced association strength in musicians and monolingual participants and as a function of time on task. Our findings, using the same paradigm and stimuli across a wide age range, suggest crossmodal correspondences are dynamic and malleable to environmental exposure.

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56.4006 On the importance of inter-sensory redundancy: Learning a new rhythmic coordination pattern using one mode (vision vs kinesthesis) can teach performance using the other mode Geoffrey Bingham[1](gbingham@indiana.edu), Winona Snapp-Childs[1], Qin Zhu[2], Shaochen Huang[2]; [1]Psychological and Brain Sciences, Indiana University, [2]Kinesiology and Health, University of Wyoming

Introduction: Many studies have shown that rhythmic movement coordination entails use of perception to couple the movements. Different sensory modalities can be used (e.g. vision versus kinesthesis). However, it is unknown whether learning via one modality allows one to perform the learned coordination using another modality, and if so, whether this is immediate (amodal information) or requires time to allow one modality to train another. Methods: To examine this issue, we trained two groups of participants (10Ss each) to produce 90° rhythmic coordination either visually (unimanual) or kinesthetically (bimanual), then tested whether the learning transferred to performance with the other modality, either immediately or after practice producing 90° with inter-sensory redundancy (i.e. with both visual and kinesthetic information available). Results: Both groups: 1) learned 90° similarly; 2) showed little immediate transfer to the untrained single modality condition; 3) were able to use the redundancy condition to train the untrained modality. Adding the untrained modality in the inter-sensory redundancy condition impaired learned performance more for the visually trained group. Conclusion: The results show that learning to detect and use relevant information in one modality does not allow one to be able to immediately detect and use the information in another modality. Nevertheless, one modality can teach another when cross training is allowed.

56.4007 Visuo-Haptic 3D Interpolation Shapes Amodally Completed Angles Walter Gerbino[1](gerbino@units.it), Joanna Jarmolowska[1], Carlo Fantoni[1]; [1]Psychology Unit, Department of Life Sciences, University of Trieste

According to action-perception coupling, extraretinal signals can disambiguate optic information, as in the contribution of head movements to the visual interpolation of twisted surfaces (Fantoni, Gerbino, Milani, Domini, JoV 2014). Going beyond approaches that exploit only the geometry of optic fragments, we focus here on the integration of self-generated haptic and optic information in 3D amodal completion. Does the precise shape of interpolated 3D surfaces depend on haptic information? We asked observers to reach and touch the nearest (visually amodal) portion of a convex 90° random-dot dihedron centrally occluded by a horizontal bar, glowing in the dark at eye height, with its virtual edge in the 500-550 mm depth range along the sagittal axis. As soon as the observer moved her hand, our HighRes Virtual Reality environment generated the 3D structure and a “magic finger”, marked by a light point that provided a visual feedback of the index tip. The finger could go through the occluder and reach the amodally completed surface, conveying a tactile feedback. Using four coplanar gauge probes and four randomly interleaved staircases we measured the location of the (visually amodal) surface while the observer was (modally) touching it in three visual feedback conditions: normal (coincident with the actual finger position); 70-mm farther away; 70-mm closer. Relative to the normal feedback, the farther feedback molded the interpolated surface towards the good continuation solution, as if it were attracted by the objective index position (not the visually experienced one); while the closer feedback molded the interpolated surface farther away, in the direction of the minimal path solution. This is the first evidence of visuo-haptic 3D interpolation: when generating amodal surfaces, our “shape modeler” includes modal haptic information (derived from hand proprioception), going beyond geometric constraints defined by the co-circularity of optic fragments.

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56.4008 Visuo-haptic cue integration in older adults Oh-Sang Kwon[1](oskwon@unist.ac.kr), Philip Jaekl[2], Olga Pikul[2], David Knill[2], Duje Tadin[2,3]; [1]Department of Human Factors Engineering, Ulsan National Institute of Science & Technology, Ulsan, South Korea, [2]Center for Visual Science & Dept. of Brain and Cognitive Sciences, University of Rochester, NY, USA, [3]Department of Ophthalmology, University of Rochester, Rochester, NY, USA

In the causal inference model of multi-sensory cue integration (Körding et al., 2007) the integration of sensory signals from multiple modalities is determined by the discrepancy between sensory signals. Crossmodal integration is the strongest when signal discrepancies are small. When signal discrepancies are large, the perceptual system assumes that the signals are caused by different sources. Consequently, the influence of one modality on another is flexibly adjusted in a manner contingent on the degree of crossmodal signal discrepancy. Little, however, is known about how aging affects this adaptive crossmodal integration. Methods: 10 older adults (age>60) and 10 young adults participated in a motion direction judgment task. In the vision condition, subjects reported the motion direction of random dot motion. In the haptic condition, subjects reported the motion direction of visually occluded right hand motion that was controlled by a robot arm. In the multimodal condition, haptic motion and visual motion were presented synchronously. In 40% of multimodal trials, both hand and dot direction were identical, whereas in the remaining trials their motion differed by 7, 15, 30, or 50 deg. Participants were always asked to report the direction of visual motion. Results: For young adults the weight of hand motion on their visual estimates significantly decreased from 0.45 to 0.16 ($F(3,27)=10.28$, $p=.0001$) as the discrepancy between visual motion and hand motion direction increased from 7 deg to 50 deg. This result is consistent with the prediction of the causal inference model. For older adults,, there was no significant change in the weight of hand motion ($F(3,27)=0.93$, $p=.43$). The interaction between group and discrepancy was significant ($F(3,54)=3.54$, $p=.021$). Conclusion: These results show that older adults do not adaptively adjust their cue combination strategy in a manner that depends on the discrepanc

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56.4009 Boundary location of remembered area is determined based on object-centered coordinates Takuma MURAKOSHI[1](murakoshi.takuma@chiba-u.jp), Eiji KIMURA[1], Makoto ICHIKAWA[1]; [1]Faculty of Letters, Chiba University

We investigated based on which spatial coordinate system, object-centered or ego-centered, the remembered area in boundary extension experiments was determined using both visual and motor tasks. On each trial, a partial image of a natural scene was presented for 3 sec (observation phase), followed by a mask of 1 sec. Participants were asked to choose the name of an object included in the image (recognition phase) and then to indicate the boundaries of the remembered area on the full-size image (test phase). In the visual task, participants adjusted the position of visually-presented lines so as to correspond to the boundaries of the remembered area. In the motor task, participants touched the screen to indicate the location of the boundaries. Between the observation and test phases, the center of the image was shifted according to different coordinate systems. In the ego-centered-shift condition, the image center was shifted leftward or rightward in ego-centered coordinates, but remained fixed in object-centered coordinates. In contrast, in the object-centered-shift condition, the image center was shifted leftward or rightward in object-centered coordinates, but remained fixed in ego-centered coordinates. In the control condition, the image center remained fixed in both coordinates. Results showed that the shift of image center affected the performances similarly in the visual and motor tasks, although the remembered area was generally narrower in the motor task. Moreover, in the object-centered-shift condition, the remembered area was narrower than that in the other conditions and shifted toward the image center of the full size image. In contrast, in the ego-centered-shift condition, the remembered area was nearly the same in location and size as that in the control condition. Stronger effects of the object-centered shift suggest that the boundary of the remembered image is determined according to object-centered coordinates in both visual and motor systems.

56.4010 Object localisation using visual to tactile and visual to auditory sensory substitution Dustin Venini[1](dustinvenini@gmail.com), Ernst Ditges[1], Nicholas Sibbald[1], Hayley Jach[1], Stefanie Becker[1]; [1]School of Psychology, The University of Queensland

With over 285 million visually impaired people worldwide there is growing interest in sensory substitution -- a non-invasive technology substituting information from one sensory modality (e.g., vision) with another sensory modality (e.g., touch). Previous work has focused primarily on how blind or vision-impaired people discriminate between different types of objects using sensory substitution devices (SSDs). A fraction of this work has explored whether and to what extent SSDs support precise localisation of objects in space; these studies report target location errors of around 8-14 cm. Here we investigated the object localisation ability of visually impaired participants using a visual to auditory (the vOICe) and a visual to tactile (custom built) SSD. In three separate conditions participants had to point to a white disk presented against a black background on a touchscreen. In the first task the SSD conveyed information only about the location of the disk, in the second task the participant’s hand was displayed in addition to the disk, and in the third task a white reference border marking the monitor frames was also added to the display. We found participants were slightly more accurate overall than in previous studies (< 6 cm error), however localisation accuracy did not significantly

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differ across the three conditions. Participants' responses were slower in the "hand" and "reference" conditions, suggesting that the additional information acted like a distractor, rendering the task more difficult. This result suggests that the processing of otherwise visual information via the auditory and tactile modalities is severely limited, especially when multiple objects are presented in parallel, suggesting that filtering of relevant information is critical to enhancing performance of future SSDs.

56.4011 **Allocentric and egocentric contribution to manual interception by moving actors.** Florian Perdreau[1](f.perdreau@donders.ru.nl), Robert van Beers[1,2], Pieter Medendorp[1]; [1]Donders Institute for Brain, Cognition & Behaviour, Radboud University Nijmegen, Nijmegen, Netherlands, [2]Department of Human Movement Sciences, MOVE Research Institute Amsterdam, Vrije Universiteit, Amsterdam, Netherlands

Previous studies suggest that the brain combines egocentric and allocentric cues to estimate the location of objects in the world. It remains unclear how the brain would combine these cues to immediately act upon objects in dynamic environments. For example, intercepting a moving object while we are moving requires us to predict the object's future location by compensating for our own displacement. In this situation, using allocentric information about the object location could improve this estimate as long as it carries reliable cues about the object's location. To test this hypothesis, we designed an interception task in virtual reality. While being moved using a vestibular motion platform and as soon as they received an auditory cue (response signal), participants had to intercept a virtual ball (target) moving in 3D with a virtual paddle that they controlled with a linear guide. The target was presented in isolation ("target only") or surrounded by two other balls (landmarks) moving along a similar trajectory. The target disappeared 250 ms before the landmarks, which were removed at the response signal. We manipulated the landmarks' reliability by varying the spatial variance of their trajectory. Both with and without self-motion, we found that increasing the landmarks' variability resulted in an increased reaching error and variability as compared to the "target only" condition, whereas the presence of "noiseless" landmarks reduced reaching error and variability compared to the "target only" condition. Our results show that while performing an interception task, the brain does integrate allocentric information with egocentric information in order to predict the object's position, even if it is at the cost of a noisier estimate. These results may be accounted for by a Bayesian model that combines predictions about the target location based on its last observation and the actual observation of the landmarks' dynamics.

Acknowledgement: This research was supported by a VICI grant to W.P.M.

56.4012 **Proprioceptive Influences on the Processing of Visual Targets: An ERP Study** Catherine Reed[1](clreed@cmc.edu), Daivik Vyas[1], John Garza[2], William Bush[3], Shaun Vecera[3]; [1]Claremont McKenna College, [2]University of Nebraska, Lincoln, [3]University of Iowa

Behavioral studies have demonstrated facilitated detection of targets located near the palm compared to far from the hand. This facilitation has been attributed to an integration of visual, proprioceptive and haptic inputs. Recent ERP studies have documented hand position influences on visual processing at both early N1 and later P3 components. In this study, we investigated whether proprioception without visual input of hand location contributes to these effects. In a go-nogo visual detection paradigm, participants viewed centrally presented stimuli between two occlusion panels that blocked the view of the hand. Hand position was varied so that the hand was held behind the panels, either near or far from the visual stimuli. EEG/ERP data indicated that with only proprioceptive information about hand location, N1 amplitudes were similar for both near and far hand conditions. However, near hand conditions produced larger target vs. non-target differences for P3 amplitudes than far hand conditions. This near hand advantage can be attributed to greater P3 amplitudes for targets compared to far hand conditions. These results suggest that although proprioceptive influences do not appear to have a strong effect early in processing, they are evident at later stages. Thus, visual input of the hand's location may be necessary to draw visual attention to intended-action objects ("targets" vs. "non-targets") at the N1, but proprioceptive information about hand location emerges later at the P3 to enhance visual target processing.

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56.4013 **The Vestibular Aubert-Fleischl Phenomenon** Isabelle Garzorz[1,2](isabelle.garzorz@lrz.uni-muenchen.de), Tom Freeman[3], Marc Ernst[4], Paul MacNeilage[1,2]; [1]German Center for Vertigo (DSGZ), University Hospital Großhadern, Ludwig Maximilian University of Munich (LMU), Germany, [2]Graduate School of Systemic Neurosciences (GSN), Ludwig Maximilian University of Munich (LMU), Germany, [3]School of Psychology, Cardiff University, Cardiff, UK, [4]Cognitive Neuroscience and CITEC, Bielefeld University, Bielefeld, Germany

To estimate object speed in the world, retinal motion must be summed with extra-retinal signals that tell about the speed of eye and head movement. Prior work has shown that differences in perceptual estimates of retinal and oculomotor (eye) speed lead to effects such as the Aubert-Fleischl phenomenon (AF) in which pursued targets are typically perceived to move slower than non-pursued ones. Here we demonstrate an analogous phenomenon, the vestibular AF, that results from differences in perceptual estimates of retinal and vestibular (head) speed. Subjects seated on a hexapod motion platform viewed a stereo visual scene consisting of a field of red spheres and a fixation point. In a 2IFC task, subjects indicated the interval in which the spheres moved faster in the world. In the oculomotor condition, one interval involved smooth pursuit with no retinal motion, the other stationary eyes with only retinal motion (i.e. classic AF paradigm). In the vestibular condition, the former was replaced by a "vestibular pursuit", i.e. subjects were passively rotated at the same speed as the spheres and fixation point. Yaw rotations had a raised cosine velocity profile with 1 sec duration and displacement of 3, 6, or 9 deg for the reference movement. Retinal speed was varied following an adaptive procedure to find the point of subjective equality (PSE), i.e. the retinal speed at which world-centered object speed was perceived equal to that during the oculomotor or vestibular interval. The ratio of retinal to oculomotor or vestibular speed at PSE was smallest in the vestibular condition, indicating that the vestibular AF is significantly stronger than the classic AF; this ratio did not depend on reference speed. We model the vestibular AF in the same probabilistic framework that has been used to characterize the classic AF (Freeman et al 2010).

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56.4014 **Observers have less confidence in perceiving self-motion direction from visual and vestibular information when the multimodal integration is in the optimal range** Ryo Tachibana[1,2](ryo-ta@dc.tohoku.ac.jp), William Beaudot[3], Kenzo Sakurai[4]; [1]Graduate School of Arts and Letters, Tohoku University, [2]JSPS Research, [3]KyberVision Japan, [4]Department of Psychology, Tohoku Gakuin University

Perceived directions of self-motion can be multimodally integrated from orthogonally directed visual and vestibular stimulation (Sakurai et al., 2003, 2010). When observers passively experience real oscillatory forward/backward somatic motion while viewing leftward/rightward visual flow patterns consistent with rightward/leftward body motion, their perceived self-motion direction is intermediate to those specified by visual and vestibular information individually. To extend these studies, we introduced multiple levels of angular differences between body-motion direction and visually specified motion direction. We investigated the optimal range of the multimodal integration by measuring the perceived direction of self-motion and observers' confidence ratings. Participants were seated on a rotatable chair on a motor-driven swing and wore a head-mounted display. The visual stimuli consisted of translating vertical sine-wave gratings phase-locked to the swing motions. The vestibular stimulation was from somatic oscillatory motion with one of 13 orientations of the chair (0 to 180 degrees in 15-degree intervals) relative to the path of the swing. In the 0-degree condition the participants' leftward/rightward somatic motion and its phase were congruent with the visual stimuli, while they were incongruent in other conditions. Participants were sound-cued to indicate their perceived direction of self-motion via a rod-pointing task, and then indicated their confidence of judgments with a 5-point scale. The perceived directions of self-motion were intermediate to those specified by visual and vestibular information in 60-, 75- and 90-degree conditions in a weighted combination fashion, suggesting these are optimal conditions for integration. Average confidence ratings, however, were lower in these optimal conditions than those in other conditions. The perceived directions were larger than the real somatic motion directions in 15- and 30-degree conditions, while they were close to the real somatic motion directions in 120-, 135-, 150-, and 165-degree conditions, suggesting vestibular information was dominant in multimodal integration in these conditions.

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56.4015 **Vection is facilitated by bone conducted vibration and galvanic vestibular stimulation** Seamas Weech[1](seamas.weech@queensu.ca), Yaroslav Konar[2], Nikolaus Troje[1,3,4]; [1]Department of Psychology, Queen's University, Kingston, [2]School of Psychology, University of Ottawa, [3]Department of Biology, Queen's University, Kingston, [4]School of Computing, Queen's University, Kingston

The illusory sense of self-motion that can occur when the visual field moves coherently ('vection') has revealed key insights into how sensory information is integrated. In the natural environment, moving through space generates an immediate perception that we are in motion. In the case of illusory self-motion, there are delays in the region of 5-10 seconds between seeing the visual field move and the feeling of vection. It has been suggested that this delay occurs due to the lack of concurrent vestibular signals accompanying visual motion onset. Any reduction in this delay could improve virtual reality (VR) immersiveness and potentially reduce 'simulator-sickness'. Researchers have attempted to reduce visual-vestibular mismatch using a technique that applies electrical stimulation to the vestibular organs, known as galvanic vestibular stimulation (GVS). Applying GVS can modulate vection and can visibly reduce nausea in VR. However, GVS is an invasive stimulation method that requires significant expertise to use appropriately. Here, we tested two techniques with the potential to provide similar benefits to GVS that are minimally invasive: chair vibration, and bone conducted vibration (BCV) applied to the mastoid processes. We examined vection magnitude and latency for wide field visual rotations, applying transient stimulation either concurrently or asynchronously with the start of visual motion. We found that both GVS and BCV, but not chair vibration, reduced vection latency compared to control when applied at the same time as visual motion onset. This difference vanished when stimulation and visual motion onset were asynchronous. Inspection of vection magnitude responses indicated no consistent differences across conditions. While we had used only roll for visual motion in the first experiment, a second experiment confirmed the same effects for yaw and pitch rotation. We therefore propose BCV as a promising candidate for reducing simulator sickness and increasing immersiveness in virtual environments.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

56.4016 **Oral Exposure to Glucose Affects Perception of Spatial Layout** Jonathan Zadra[1](j.zadra@utah.edu), Dennis Proffitt[2]; [1]Department of Psychology, University of Utah, [2]Department of Psychology, University of Virginia

Previous studies have shown that the perceptual metric for walkable distances is bioenergetic. People perceive hills to be steeper and distances to be greater when encumbered or fatigued, and supplementation of bioenergetic resources causes the reverse: participants who complete a task to deplete blood glucose levels and then drink an artificially sweetened placebo beverage estimate hills to be steeper and distances to be greater than participants who instead drink a beverage containing glucose (glucose is the primary fuel for short-term physical activity). In exercise physiology, it is very well established that glucose supplementation enhances athletic performance. Interestingly, introducing carbohydrate solutions to the mouth but prohibiting any ingestion (i.e., rinsing and spitting) can also enhance performance. These findings suggest that the relationship between glucose levels and physical performance is not entirely reactionary with regards to momentary blood glucose levels. It seems that signals that would normally indicate an upcoming increase in blood glucose may trigger either physiological or cognitive processes (or both) that result in the same increase in performance as an actual glucose increase. Because a bioenergetic perceptual scale reflects the perceiver's ability to act, any factor that affects physical or athletic performance should also affect perception of spatial layout. To test whether oral exposure to glucose without ingestion would affect perception of walkable distances, the following experiments had participants chew and spit out gelatin sweetened either with artificial sweetener or glucose and then judge the slant of a hill (Experiment 1) or a series of distances to makers in a flat field (Experiment 2). In line with the effects of oral glucose exposure on physical performance, participants in the glucose conditions perceived hills to be shallower and distances to be shorter, respectively.

Binocular Vision: Rivalry and bistability

Tuesday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4017 **The role of parietal cortex during probe-accelerated binocular rivalry** Brian Metzger[1,2](bmetzge2@illinois.edu), Kathy Low[2], Edward Maclin[2], Gabriele Gratton[1,2], Monica Fabiani [1,2], Diane Beck[1,2]; [1]Department of Psychology, University of Illinois, [2]Beckman Institute for Advanced Science and Technology

Binocular rivalry occurs when dissimilar images are presented simultaneously but separately to corresponding retinal locations of each eye. Perception alternates between the two images such that one image dominates awareness while the other is suppressed. Prior research has shown that probes presented to the suppressed eye accelerate reversals. We've shown that these reversals are mediated by P1 amplitude (Metzger et al., VSS 2014; CNS 2015) such that P1 amplitude increases monotonically as a function of reversal latency (from probe onset), that P3b activity tracks reversal-related activity such that P3b peak latency coincides with reversal latency (Metzger et al., SPR 2015), and that activity in left and right superior parietal lobules precede the button response (i.e beginning of the reversal; Metzger et al., SfN 2015). However, the role and timing of parietal cortex relative to the transition from one percept to the other remains unclear (c.f Frassle et al., 2014; Brascamp et al., 2015). One possibility is that parietal cortex becomes active as a consequence of a change in perception. Another possibility is that parietal cortex initiates and/or facilitates changes in perception, becoming active prior to the reversal. Here, we used fast-optical imaging (EROS) to determine the timing of parietal activation relative to reversals. Percept-specific changes in cortical activity (i.e. OFA/LOC and collateral sulcus for face and texture percepts respectively) suggest that reversals begin ~384 ms prior to button release. Furthermore, these percept-specific areas oscillate in-phase with parietal activity. Critically, however, Granger causality analyses suggest that activity in rSPL precedes activity in percept-specific areas by about 75 ms, with a second peak in lSPL and rSPL during or soon after the reversal. Taken together, our data suggest that in the case of probe-accelerated reversals, parietal areas become active either to initiate, or to facilitate changes in perception during binocular rivalry.

56.4018 **Similar spatial decencies for image- and eye-based integration during binocular rivalry** Sjoerd Stuit[1](s.m.stuit@uu.nl), Maurits Barendregt[1], Maarten Smagt [1], Susan te Pas[1]; [1]Experimental Psychology, Utrecht University

Binocular rivalry occurs when the information presented to the two eyes is inconsistent. Instead of fusing into a single stable image, perception alternates between multiple interpretations over time. Integration across space during rivalry can be affected by image content. Visual information presented to the same eye tends to be integrated into a dominant percept most of the time. This suggests that integration across space during rivalry occurs mostly at an early monocular level of processing. However, recent evidence suggest suppressed images are still represented at multiple levels of the visual processing hierarchy. This suggests that competition, and therefore also integration across space based on image-content also occurs at multiple stages of processing. Here we test this idea by capitalizing on known properties of the visual processing hierarchy. Since later visual areas have increasingly larger receptive fields, image-based integration should continue to facilitate dominance durations for integrated image-parts that are presented further apart. Eye-based integration, on the other hand, should decrease at larger image-part distances (IPD) since monocular channels are lost after the earliest stages of visual processing. We investigate eye- and image-based integration as a function of image-part distance (IPD). Results show that dominance durations are relatively stable when based on either image- or eye- integration. Moreover, effect sizes reveal that both eye-based and image-based integration have a similar relation with IPD. This suggests that image-based and eye-based rivalry occur at the same level of processing. Therefore, the formation of a dominant image does not appear to require integration at a later stage of visual processing.

56.4019 **Playing visual dominance of score on the piano: Skilled motor action matters in the awareness of musical notes during binocular rivalry, only when accompanied by auditory feedback** Sujin Kim[1](preikestolen89@gmail.com), Chai-Youn Kim[1]; [1]Department of Psychology, Korea University

Previous studies in our group showed that a visual musical score viewed dichoptically with a radial grating enjoyed longer dominance durations when presented with an auditory melody congruent to that score (Kim et al., VSS 2014; Lee et al., 2015). It has also been reported that an action relevant to a visual interpretation contributes to resolve perceptual ambiguity during binocular rivalry (Beets et al., 2010; Maruya et al., 2007). In the present study, we investigated whether a skilled motor action linked tightly to one of the two rival targets affects audiovisual interaction during rivalry. Sixteen observers with varying degree of piano playing skill viewed dichoptically a musical score scrolling from right to left within a viewing window and a counter-phase flickering radial grating. The perceptual dominance of visual musical score was tracked by playing the musical notes on the midi keyboard, while the grating dominance was tracked by pressing a button on a computer keyboard. On "sound" trials, participants heard the sound of piano being played by themselves. On "no sound" trials, auditory feedback was not accompanied by keyboard playing. Results showed a positive correlation between the degree of piano playing skill and the normalized score-dominance durations, only when the auditory feedback was accompanied. Accordingly, observers were divided in two groups based on the skill. In the more-trained group (8.3 ±0.89 years in training, N=8), the normalized score-dominance durations with auditory feedback were distributed toward the longer side than without auditory feedback, while there was no such effect observed in the less-trained group (3.6 ± 0.56 years, N=8). These results suggest that an execution of skilled motor action closely linked to a visual stimulus has impact on the interaction between the visual stimuli and the auditory feedback during binocular rivalry, which relies on the mastery of the motor skill.

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56.4020 **Contrast-modulated stimuli in competition with luminance-modulated stimuli under binocular rivalry conditions** Jan Skerswetat[1](jan.Skerswetat@anglia.ac.uk), Monika Formankiewicz[1], Sarah Waugh[1]; [1]Anglia Vision Research, Department of Vision and Hearing Sciences, Anglia Ruskin University, Cambridge, U.K.

Binocular rivalry demonstrates perceptual competition, when dissimilar stimuli are presented separately to each eye. Results of previous investigations on rivalry suggest that luminance-modulated noise (LM) and contrast-modulated noise (CM) stimuli engage different processing sites because of the different proportions of visual exclusivity reported (Skerswetat et al. VSS 2014, ECVP 2015). We presented an LM grating to one eye and an orthogonal CM grating to the other, to investigate how these are perceived when competing under binocular rivalry conditions. Stimulus size was 2 deg, the spatial frequency was 2 c/deg. Sine-wave gratings were constructed from correlated binary noise with a contrast-amplitude of 0.20. The modulation of the CM-grating was fixed at 1.00 (visibility level of ~7x). LM-grating contrast varied from 0.04 to 0.78 (visibility levels of ~2x to 44x). A trial lasted at least 120 seconds. Each CM/LM condition was carried out 8 times. Ten participants indicated via response box button presses the following perceptual states: exclusively visible, completely superimposed, or piecemeal. When the two stimuli were of similar visibility (~5-7x), the CM stimulus was exclusively visible for 45% of trial time whereas the LM stimulus, for only 7%. An increase in LM visibility, resulted in an increase in visual exclusivity of the LM grating from 2 to 18%, and a reduction of the CM-grating from 78% to 21%; the mean dominance duration for the LM grating increased from 0.9 to 1.3 sec, and reduced for the CM grating from 24 to 1.3 sec. For both visual exclusivity and mean dominance duration, the interaction between stimulus type and LM visibility was significant [$p < 0.05$]. The results have shown that inter-ocular stimulus strength (Levelt, 1965), does not necessarily drive perceptual predominance during binocular rivalry, but that stimulus type and processing site also need to be considered.

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56.4021 **Responses of orientation-tuned channels in human visual cortex during binocular orientation rivalry** Chao Shi[1,2,3](shichao@pku.edu.cn), Junshi Lu[1,2,3], Fang Fang[1,2,3]; [1]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), [2]Peking-Tsinghua Center for Life Sciences, [3]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing 100871, P.R. China

Incompatible stimuli presented to two eyes compete for representation and awareness. This phenomenon is referred to as binocular rivalry. To date, the neural mechanisms of binocular rivalry remains elusive. Here, we used an fMRI encoding model to reconstruct the responses of hypothetical orientation-selective channels while subjects viewed two orthogonally gratings presented dichoptically. Subjects participated in one training session for weight estimation and two to four binocular rivalry/replay sessions for reconstruction. In the training session, contrast-reversing sinusoidal gratings at six possible orientations (15°, 45°, 75°, 105°, 135°, and 175°) were presented. In the binocular rivalry/replay sessions, for each rivalry run, 15° and 105° oriented gratings were presented dichoptically for 90s and subjects pressed one of three buttons to report their perception. Each rivalry run was immediately followed by a replay run which mimicked the subject's perception in the preceding rivalry run. Using the estimated weights from the training session, for each visual area, we decomposed the spatial pattern of fMRI activation into responses of orientation-tuned channels. We compared the channel responses between the rivalry and replay conditions, and found that, in the rivalry condition, the channel response to the dominant orientation was weaker than that in the replay condition. In contrast, the channel responses to the suppressed orientation in the two conditions showed the opposite pattern. These effects were most pronounced in V1 and attenuated in V2 and V3. In V4, the channel response patterns in the rivalry and replay conditions became indistinguishable. These results revealed how binocular rivalry affected the neural representations of dominant and suppressed orientations in the visual hierarchy of human brain and suggest that substantial suppressed information during binocular rivalry is still represented in early and intermediate visual areas.

56.4022 **A binocular context exerts a similar influence on both binocular rivalry and ambiguous figure perception** Marouane Ouhnana[1](marouane.ouhnana@mail.mcgill.ca), Ben Jennings[1], Frederick Kingdom[1]; [1]McGill Vision Research Unit, Department of Ophthalmology, McGill University

Aim: Images that resist binocular fusion undergo alternating periods of dominance and suppression, similar to ambiguous figures, whose percepts alternate between different interpretations. It has been well documented that a binocularly rivalrous target that forms part of a global form in the same eye tends to become perceptually dominant. This parallels similar effects of spatial context in ambiguous figure perception. Here we examine whether binocular rivalry exhibits perceptual binding properties to a binocular spatial context that parallels the effects shown by us at VSS last year for ambiguous figures (Ouhnana & Kingdom, 2015 JOV, 15.12, 842). Method: Observers indicated via key-press the perceived motion direction of a skeleton cube rotating in opposite directions in the two eyes, or of a rotating ambiguous Necker cube cube, with both types of stimuli presented above or below a fixation dot. A rotating unambiguous context skeleton cube was presented the other side of fixation. The rotation direction of the context figure was randomly changed during each 30s trial. The data was subject to a form of reverse correlation analysis that established the correlation between the motion reversals of the context and that of the target figures. Results: The perceived changes in motion direction of both the rivalrous- and ambiguous-target figures were found to be dependent on the motion of the spatial context. Both correlations and coherent percept predominance of context and target were found to be significantly higher than would be expected if these two were independent. Conclusion: Perceptual binding of both rivalrous and ambiguous figures to a spatial context appear to be mediated by a similar shared rivalry/ambiguity process.

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56.4023 **The development of binocular suppression in infant** Jiale Yang[1](jiale.yang.ac@gmail.com), So Kanazawa[2], Masami Yamaguchi[1]; [1]Chuo University, Japan, [2]Japan Women's University, Japan

Several studies have reported that the function of binocular fusion starts at 2-3 month of age (Braddick et al., 1980; Petrig et al., 1981; Skarf et al., 1993) and the sensitivity to horizontal disparity emerges around 3–4 months of age (Birch, 1993; Kavšek, 2013). However, little is known about when binocular suppression emerges. The present study evaluated the development of binocular suppression in infants by using continuous flash suppression (CFS, Tsuchiya & Koch, 2006). In our experiment, one eye of infants presented with a static face image at one side of the screen, while another eye is presented with a series of rapidly changing Mondrian patterns in full screen. Adult observers confirmed that the static face image was consciously repressed by the changing Mondrian patterns. If the binocular suppression has functioned, the infant would not perceive the face as adults, and show no preference in the experiment. However, if the infant have not acquired binocular suppression, they would perceive the face and the Mondrian patterns at the same time, so that these infant would prefer to look at the side where the face was presented. The results showed that infants aged 2-3 months, but not 4-5 months, preferred the face. These results indicated that the immature binocular visual system may perceive different images from different eyes simultaneously, and the infant may lose this ability after establishing binocular suppression at 4-5 months of age.

56.4024 Eye of origin is critical for robust continuous flash suppression

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Purpose: A salient stimulus in one eye can be rendered invisible by presenting a high contrast flickering grating to the other eye (continuous flash suppression, CFS). This study investigated the effects of eye of presentation (which eye received which stimulus) on strength of CFS. Method: The suppressing stimulus (suppressor) was a counterphase-flickering (5 Hz) vertically-oriented Gabor patch (2.5 cpd, sigma = 0.22 degrees, and 100% contrast). The target was a horizontally-oriented Gabor patch of the same spatial properties (40% contrast). Eye of presentation was manipulated in three conditions. In the dichoptic condition, the suppressor and the target were presented at the same retinal position of different eyes, whereas in the monocular condition they were presented to the same eye. In the eye-swap condition, they were presented to different eyes but eye of presentation was repeatedly swapped at 1 Hz. On each trial, the suppressor was initially presented alone to establish perceptual dominance and 0.5 - 2 sec later the target was introduced. The contrast of the target was gradually increased to 40% over a 1-second period and then remained constant. We asked observers to detect the target as soon as possible and measured detection time. Results & Discussion: In the dichoptic condition, the detection time was long (Mean = 4.74 sec), indicating robust CFS. In the eye-swap condition, however, the target was detected much faster (Mean = 2.52 sec) and the detection time was not significantly different from that in the monocular condition (Mean = 1.51 sec). These results showed that disrupting the eye-of-origin information almost eliminated the potency of CFS. The present findings suggested that CFS is mainly mediated by eye rivalry (rivalry between the eyes) rather than stimulus rivalry (rivalry between stimuli).

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56.4025 Faster motion takes priority: Interocular dynamic suppression of motion is primarily salience-based rather than feature-selective

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Binocular rivalry occurs when conflicting visual information is presented to two eyes, whereby the percept in one eye is said to “rival” the percept in the other eye. In continuous suppression paradigm, one of the percepts (mask) is intentionally made more salient than the stimulus of interest presented to the other eye. However, the classical continuous flash suppression (CFS mask) appears to be less effective in suppressing continuous motion, while the more effective dynamic mask was found to be feature-selective, i.e., matching the speed of the mask elements to the speed of the stimulus led to best suppression (Moors, Wagemans, de-Wit, 2014). Contrary to the latter finding, the results of the present study indicate that dynamic suppression may be primarily salience-based rather than feature-selective. More specifically, the effectiveness of suppression was contingent upon the paradigm used: when potential confounds, such as discontinuity of motion, were eliminated, the faster moving masks lead to more effective suppression, suggesting that dynamic suppression is primarily driven by the salience of the mask. This was confirmed in both 2D and 3D paradigms. The implications of these findings for models of suppression (how stimuli rival for consciousness), as well as feature-specific contributions, are discussed.

56.4026 Binocular summation of chromatic information

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While there are studies for binocular summation of luminance contrast, how the visual system integrates chromatic information from the two eyes is not well understood. We designed a matching experiment to measure the binocular summation of isoluminance colors. The stimuli were dichoptically viewed squares (2 by 2 degree) modulated in one of the six color directions (L-M, M-L, +S, –S, L+M+S and –L-M-S). In each trial, an observer would see a test square, which was a combination of the squares presented to the left and the right eyes in different contrast, and a match square, in which the contrasts of the left and the right eye squares were the same. The ranges of contrast, expressed in dB (20*log10C, where C is Michelson contrast), were,from -42 to -18 dB for L-M, -18 to -2 dB for S and -32 to -8 dB for L+M+S directions.. The observers’ task was to adjust the contrast of the match stimulus to match the test stimulus. In general, the matched contrast increased with test contrast. When the test contrast difference between the two eyes was small, the match was approximately the average of the patch contrasts of both eyes with slightly greater weighting for the dominant eye. However, when the contrast difference between the two eyes was large, the match result was dominated by the higher contrast, regardless of the eye origin. Such change of relative contribution from the two eyes by contrast cannot be explained by a linear model in which the perceived binocular contrast was predicted by the linear combination of two monocular contrasts. Instead, a nonlinear model is necessary to explain the data.

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56.4027 Differential effects of interocular suppression on the pupillary constriction and dilation

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This study produced different perceptual changes using physically-identical binocularly-rivalrous stimulus sequences and investigated the effects of interocular suppression on the pupillary response. When a white and a black disk were presented at the same retinal position of different eyes, binocular rivalry can be experienced. We asked observers to press a key when one of the disks (e.g., black disk) became exclusively dominant. Then just after the key press, we switched the dichoptic stimuli to binocular white disks (WW condition) or binocular black disks (BB condition). Depending on the initial dominant percept, the stimulus sequence produced different perceptual changes. For example, when the initial percept was black, a black-to-white perceptual change was produced in the WW condition. However, in the same WW condition, a white-to-white change was produced when the initial percept was white. We measured the pupillary response during these stimulus sequences. Results showed that the direction of the pupillary response was determined by the physical stimulus change; i.e., the pupil constricted to the stimulus change in the WW condition, whereas it dilated in the BB condition. However, the constriction and dilation amplitudes were modulated in conjunction with the perceptual change in brightness. In the WW condition, the constriction was larger when the perceptual change was black to white than when it was white to white. Similarly in the BB condition, the dilation was larger when the perceptual change was white to black. Moreover, the modulating effect of interocular suppression was more consistent on the dilation; i.e., significant modulation was found for all observers in the dilation, but for 8 of 12 observers in the constriction. These results indicate that the pupillary dilation is a more reliable measure of interocular suppression and may suggest that interocular suppression differentially affects the pupillary pathways mediating the constriction and the dilation.

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56.4028 Spatiotemporal BOLD correlates of switches in bistable perception

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When the left and the right eye receive incompatible images simultaneously, the observer typically reports perceiving one of the two images at a time, with perception switching between the eyes’ images over time. These switches are accompanied by transient BOLD responses occurring across the whole brain, from the highest to the lowest levels of cortical visual processing. In parallel, the chain of cognitive events surrounding a perceptual switch is a complex one, ranging from causative processes to arousal, attention and motor response selection. To assess the relative functional roles of switch-related brain responses we investigated their time course and spatial specificity in detail. We acquired simultaneous fMRI (< 1s TR) and 1kHz eye tracking data from 9 subjects during a binocular rivalry task. It is known that a considerable proportion of switches is caused by blinks and eye movements, likely due to visual transients. Our simultaneous ocular and imaging data allowed us to specifically analyze switch-related activations not tied to ocular events. We found that these endogenously caused events trigger transient BOLD responses from V1 to inferior frontal cortex. In V1, switches caused activations which are not limited to the retinotopic footprint of the binocular rivalry stimulus. Instead, these responses were retinotopically global, spanning the representation of the whole of visual space. Furthermore, switch-related response time courses from all regions had an unusual biphasic shape, starting with a strong negative dip. This temporal response profile was duplicated in the pupil’s responses to these same events. By articulating the spatiotemporal elements of the brain’s responses to perceptual switches, we may start to link them to their specific cognitive concomitants. Our novel findings provide insight in the brain network involved in switching during bistable perception, and allows for a fuller understanding of these networks’ roles in perception and cognition.

 See page 3 for Abstract Numbering System

56.4029 The temporal frequency tuning of CFS: peak suppression at low frequencies Shui'Er Han[1](han.shuier@gmail.com), Claudia Lunghi[2,3], David Alais[1]; [1]School of Psychology, Brennan MacCallum Building, University of Sydney 2006, New South Wales, Australia, [2]Department of Translational Research on New Technologies in Medicine and Surgery, University of Pisa, Pisa, Italy, [3]Institute of Neuroscience, CNR – Pisa, Via Moruzzi 1, 56124 Pisa, Italy

Continuous flash suppression (CFS) is a psychophysical technique where a rapidly changing Mondrian pattern viewed in one eye suppresses the target in the other eye for several seconds. Despite its widespread use in the study of awareness and unconscious processing, the temporal tuning of CFS remains surprisingly unknown. Previous studies have examined the effect of varying the Mondrian refresh rate, but this is not equivalent to manipulating temporal frequency in a pattern that varies randomly in luminance from frame to frame. In this study, we map the temporal frequency tuning of CFS using temporally narrow, bandpass-filtered noise maskers. Our results show that, contrary to common assumption, slower masker refresh rates (e.g., 0.75-1.5 Hz) supress targets for longer durations compared to faster masker refresh rates (e.g., 10 Hz and above). These results seem to reflect a parvocellular bias in CFS, since the low temporal frequency trend was more pronounced with high spatial frequency targets compared to low spatial frequency targets. In addition, raising masker contrast was found to increase suppression duration, but only if the masker modulated at a low temporal frequency (i.e., 2 Hz).

56.4030 Traveling waves in motion-induced blindness Dustin Cox[1](dcox2013@fau.edu), Sang Hong[1]; [1]Florida Atlantic University

There is mixed evidence regarding whether motion-induced blindness (MIB) and binocular rivalry (BR) may share a common mechanism based on comparisons of their respective temporal perceptual switching dynamics. To address this inconsistency, we examined both spatial and temporal dynamics of perceptual switching in MIB to determine whether they resemble those in binocular rivalry. Perceptual transitions in binocular rivalry are commonly experienced as traveling waves of dominance and suppression. Traveling waves of dominance and suppression begin locally and gradually expand as stimulus visibility or invisibility spreads over remaining portions of a stimulus across space and time, respectively. Traveling waves in BR also exhibit collinear facilitative effects as indicated by briefer perceptual transitions for collinear-patterned stimuli in comparison to those with radial patterns. If MIB and BR share a common mechanism, perceptual transitions in MIB should not only occur in a gradual manner across space and time, but visibility transitions should occur more efficiently for collinear- in comparison to radial-patterned MIB target stimuli. Participants viewed a display consisting of a rotating grid of black crosses on a grey background and a static arc-shaped target with a radial- or collinear-patterned internal configuration. In each trial, participants held a key once a target was fully suppressed by MIB, which triggered target reappearance via a transient contrast change at the ending portions of the target. We found that collinear-patterned MIB targets completely disappeared and reappeared with briefer latencies in comparison to those of radial-patterned targets. This result indicates the common spatiotemporal dynamics of perceptual transitions in MIB and BR, which suggests that these phenomena indeed share a common mechanism.

56.4031 Causal events enter awareness faster than non-causal events Pieter Moors[1](pieter.moors@ppw.kuleuven.be), Johan Wagemans[1], Lee de-Wit[1,2,3]; [1]Laboratory of Experimental Psychology, Department of Brain & Cognition, University of Leuven (KU Leuven), [2]Institute of Continuing Education, Madingley Hall, University of Cambridge, [3]Cognition and Language Sciences, University College London

Philosophers and psychologists' alike have long debated whether causality can be directly perceived or has to be inferred (Hume, 1740; Rips, 2011; White, 2012; Michotte, 1946). Albert Michotte provided an important contribution to this discussion by presenting evidence that events can be parametrically varied such that they sometimes elicit a causal percept and sometimes do not. Based on this series of experiments, Michotte argued that human observers perceive causality, and that causality is a primary visual property such as color or motion. In this work, we asked whether causal events entered awareness faster than non-causal events, a result that would provide additional evidence for the perceptual nature of causality. In our first experiment, causal (launching) and non-causal (passing) events were presented to human observers while these events were rendered invisible through continuous flash suppression (Tsuchiya & Koch, 2005). We measured the time it took for observers to detect any part of the event. Our results indicated that launch events entered awareness faster than passing events in nearly all observers. In our second experiment, we aimed at replicating the effect observed in the first experiment and we added a control event to address differences in local motion saliency for the launch and pass event. We succeeded in replicating the suppression time difference between launch and pass events. Moreover, launch events also entered awareness faster than control events, which entered awareness equally fast as pass events. Our results therefore imply that causal percepts are at least partially constructed at early stages of visual processing, giving further weight to Michotte's perceptual account of causality perception.

56.4032 Perceptual Inferences in Schizophrenia: A preliminary study in healthy participants Pantelis Leptourgos[1](plepto12@gmail.com), Charles-Edouard Notredame[2], Renaud Jardri[1,2], Sophie Denève[1]; [1]Group for Neural Theory, DEC, ENS, Paris, France, [2]SCALab, Lille University, Lille, France

It has been suggested that aberrant inferences (circular inferences) implemented in brain networks, generating a system that overweights even weak sensory evidence could underlie the positive dimension of schizophrenia (Jardri and Denève, 2013). This hypothesis was validated by a probabilistic reasoning task (in prep.). Here we validate, with a pilot study in healthy subjects, a paradigm that allows for experimentally testing the respective impacts of sensory evidence and priors on perception in schizophrenia. Necker Cube is an ambiguous figure, known to induce bistability. Such figures were continuously presented to 50 participants during 15 consecutive runs. We manipulated sensory evidence by adding shades to the stimuli (3 last runs) and prior expectations by giving different instructions to 3 different groups (15 – 15 – 20 participants), concerning the presence of an implicit preference. Participants' responses were discretely and pseudo-regularly collected (Mamassian and Goutcher, 2005). After confirming the existence of an implicit prior ($p< 0.001$), we showed that manipulation of this prior had significant opposite effects ($p=0.009$), either by exacerbating or cancelling the intrinsic bias of the system. The effect of sensory evidence was even stronger ($p< 0.001$), and induced a significant bias corresponding to the direction of the cue. This effect was so strong that it overcame the impact of the instructions when cues and prior manipulations were combined. We also found that the behavior could be well fitted by Bayesian models ("simple" Bayes, model with Markovian statistics) with low statistical dependencies between successive time steps. This study will be used as a reference, in order to study patients with psychotic symptoms and test our initial claim.

56.4033 Heritability of individual visual abilities captured by common SNPs Zijian Zhu[1,2](zhuzijian@pku.edu.cn), Yi Rao[3]; [1]Peking-Tsinghua Center for Life Sciences, Academy for Advanced Interdisciplinary Studies, Peking University, Beijing, China, [2]State Key Laboratory of Biomembrane and Membrane Biology at the School of Life Sciences, Peking University, Beijing, China, [3]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, China

Vision research is a major topic in cognitive sciences. During the last decades, it has become a well developed research field in human neuroscience. Up to now, common visual abilities and visual phenomena have been well studied at the level of behavioral characteristics, neuronal basis, and computational modeling. In contrast, the molecular mechanisms underlying these visual phenomena have rarely been studied. A recent study has explored the heritability of binocular rivalry in twins, and has found that 52% of the phenotypic variance could be attributed to genetic factors. Here, we extended the study by exploring the narrow heritability of a bunch of visual abilities (perceptual grouping, orientation discrimination, motion discrimination, and motion detection) and vision-related phenomena (binocular rivalry, bistable perception, and Ebbinghaus illusion) in normal human subjects. We did genome-wide restricted maximum likelihood (GREML) analysis on 819,711 common SNPs. Results showed that, for perceptual grouping (70%, s.e.=0.297, n=1185), orientation discrimination (60%, s.e.=0.48, n=802), and bistable perception (89%, s.e.=0.32, n=1246), more than half of the variance could be explained by all the tested SNPs. For motion discrimination (39%, s.e.=0.34, n=1235), motion detection (37%, s.e.=0.35, n=1197), binocular rivalry (42%, s.e.=0.28, n=1369), and Ebbinghaus illusion (18%, s.e.=0.27, n=1339), the narrow heritability was smaller yet still no less than 18%. Furthermore, because the explained variance by GREML came only from contribution of all the common SNPs, the true estimated heritability of these visual phenotypes should be larger. Therefore, visual behavior might be highly heritable, and part of the variance in the visual phenomena could even be well explained by common SNPs. Taken together, these findings indicate that further studies focusing on the molecular mechanisms behind visual abilities and phenomena are needed, especially for those with high heritability (e.g. perceptual grouping, motion detection, orientation discrimination, bistable perception, and so on).

Temporal Processing: Neural mechanisms

Tuesday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4034 Visual target detection in temporal white-noise: A “universal” forward model using oscillatory impulse response functions

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Brain activity is inherently rhythmic. EEG responses to white-noise luminance sequences can serve to derive (by cross-correlation) the visual “impulse response function” (IRF), which displays large oscillatory components. The IRF can then be used mathematically (by convolution) to estimate EEG oscillatory responses to new white-noise sequences, without actually recording EEG. In turn, visual perception (e.g. for a brief target) is related to moment-by-moment fluctuations in both the phase and amplitude of brain rhythms. It logically follows that the detection of a target embedded in a white-noise sequence must be related to certain IRF features. Some of these features are subject-specific, and can serve to design noise sequences optimized for target detection by one specific observer (a form of neuro-encryption: Brüers & VanRullen, VSS 2015). Other features, however, are subject-independent, reflecting “universal” properties of perception and oscillations; these are the properties studied here. We derived a “universal IRF” by averaging EEG IRFs from 20 observers. We then created a “universal forward model” taking as input a target’s position within a white-noise luminance sequence, modeling oscillatory brain responses to that random sequence (by convolution with the IRF), and using specific features (phase, amplitude) of these modeled oscillations to output a prediction regarding the target’s visibility. The prediction was then tested on a separate group of observers. No systematic differences in white-noise sequences could explain why some targets were more visible than others (as verified e.g. using “classification images”). Yet by considering the typical oscillatory brain responses that this noise was expected to produce (without actually recording them), we could guess which targets would be detected. Oscillatory phase (and to a lesser extent, amplitude) in several frequency bands robustly predicted perception, with a peak in the theta-band (4-8Hz, ~10% modulation, $p < 0.001$). We are now exploring ways to optimize predictions by combining oscillatory features.

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56.4035 Higher N1 responses in relatives of schizophrenia patients than controls in visual backward masking

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Schizophrenia is a heterogeneous disease. To cope with this heterogeneity, we tested a large sample of schizophrenia patients (n = 80), non-affected first-degree relatives (n = 56) and matched healthy controls (n = 52), in a visual backward masking (VBM) paradigm while recording the EEG. In VBM, a target stimulus is followed by a mask, which decreases performance on the target. We had three conditions: target only and two VBM conditions, with long and short inter-stimulus interval (ISI). Patients’ performance was impaired, while the relatives performed at the same level as the controls. Performance was significantly correlated with the EEG N1 amplitude, as measured by the Global Field Power (GFP). Most interestingly, N1 amplitudes were higher in relatives compared to controls, while they were lower in patients relative to controls as previously reported. For relatives, N1 amplitudes were at the same level in all conditions; however, for controls and patients, N1 amplitudes increased with task difficult, e.g., amplitudes in the long ISI condition were lower than in short ISI condition. Our results suggest that relatives use a compensation mechanism tuning the brain to maximum performance in all conditions. Since relatives are already at the peak of their activations, increasing the task difficulty does not change brain processing.

56.4036 Electrophysiological correlates of backward masking in students scoring high in cognitive disorganization

Ophélie Favrod[1](ophelie.favrod@epfl.ch), Guillaume Sierro[2], Maya Roinishvili[3,4], Eka Chkonia[4,5], Christine Mohr[2], Céline Cappe[1,6], Michael Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, Swiss Institute of Technology (EPFL), Switzerland, [2]Faculté des sciences sociales et politiques, Institut de Psychologie, Bâtiment Anthropole, Lausanne, Switzerland, [3]Vision Research Laboratory, Beritashvili Centre of Experimental Biomedicine, Tbilisi, Georgia, [4]Institute of Cognitive Neurosciences, Agricultural University of Georgia, Tbilisi, Georgia, [5]Department of Psychiatry, Tbilisi State Medical University, Tbilisi, Georgia, [6]Centre de Recherche Cerveau et Cognition, Université de Toulouse, UPS, CNRS, 31052 Toulouse, France

Visual deficits are well documented in schizophrenia. For example, in backward masking a Vernier is followed by a blank inter-stimulus interval (ISI) and then a grating mask. Observers indicate the direction of the Vernier offset (left vs right). Patients need ISIs that are 120ms longer than in healthy controls. Interestingly, these masking deficits are reflected in strongly reduced EEG amplitudes in schizophrenia patients when compared to healthy controls. Schizophrenia is considered to lie on a continuum ranging from strongly affected patients to healthy people with schizotypic personality traits. Schizotypic traits are measured with self report questionnaires such as the sO-LIFE. In analogy to patients, schizotypic traits are divided in positive (e.g., hallucinations), negative (e.g., anhedonia) traits and cognitive disorganization (CogDis). It has been shown that healthy students scoring high in CogDis show higher masking deficits than students scoring low in CogDis. On average, high CogDis students need ISIs that are 20ms longer than in low CogDis students. Here, we show that preselected high as compared to low CogDis students show reduced EEG amplitudes, but to a lower extent than do patients. We computed the Global Field Power (GFP), which is the standard deviation across all 192 EEG electrodes. The GFP is a measure of the overall strength of brain activity. We found deficits at 200ms after stimulus onset associated with the N1 component. This component is related to ventral stream processing and fine shape discrimination. We suggest that mechanisms necessary to boost faint stimuli are deficient in schizophrenia patients and attenuated in high CogDis students. Elevated CogDis seems to be a risk factor for schizophrenia.

56.4037 Flicker adaptation and neural transmission speed in the human MC pathway

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INTRODUCTION: Flicker-induced adaptation of the human magnocelluar (MC) pathway increases contrast thresholds (Zhuang, Pokorny & Cao, IOVS 2015). This study tests whether flicker adaptation also reduces neural transmission speed for suprathreshold stimuli by measuring the response time to a suprathreshold disc. The working hypotheses are that (#1) flicker presented to a given eye can adapt the monocular pathway and also a subsequent binocular mechanism and (#2) flicker presented to both eyes causes greater adaptation at the binocular level than flicker to only one eye. METHODS: Adaptation was induced with a flickering 16x13 deg rectangular field modulated at 9.4 Hz with 100% Michelson contrast. Adaptation could be in neither eye (baseline using a steady adapting field), in only one eye or in both eyes. The test stimulus for response time, a foveal 0.5 deg diameter disc, could be presented to either eye alone or both eyes. Observers responded to the test stimulus as quickly as possible. RESULTS AND DISCUSSION: Response time was the slowest when a monocular test stimulus was presented to the same monocularly adapted eye. Surprisingly, with a monocular test the response time was significantly faster with binocular adaptation than with same-eye monocular adaptation. This suggests that when both eyes are adapted to flicker, the overall adapting effect for a monocular test is inhibited by flicker adaptation in the fellow eye. Overall, the results confirm that flicker adaptation reduces neural transmission speed for suprathreshold stimuli (consistent with working hypothesis #1), but also show that transmission speed for a stimulus presented to only one eye can be speeded up by adding adaptation in the fellow eye (contrary to #2). The latter finding corroborates a similar conclusion from measurements of monocular and binocular contrast thresholds (Zhuang & Shevell, Vision Research 2015).

56.4038 **The hidden spatial dimension of alpha: occipital EEG channels encode contralateral and ipsilateral visual space at distinct phases of the alpha cycle** Diego Lozano-Soldevilla[1,2](diegols@protonmail.com), Rufin VanRullen[1,2]; [1]Universite Paul Sabatier, Toulouse, France, [2]Centre de Recherche Cerveau et Cognition, CNRS UMR 5549, Faculte de Medecine de Purpan, Toulouse, France

Visual information is encoded periodically at alpha frequency (~10Hz): for example, a robust alpha component was found by cross-correlating visually presented white-noise (random) luminance fluctuations with corresponding EEG responses over posterior sensors (VanRullen & Macdonald, 2012). This oscillatory impulse response function can be interpreted as a ~10Hz perceptual echo that reverberates the input sequence periodically. Here, we explored the spatial dimension of these perceptual echoes. Two independent random luminance white-noise sequences were simultaneously displayed in two discs on the left and right of fixation. For each EEG channel, two echo functions could thus be computed, by cross-correlating each random luminance sequence (left and right discs) with the simultaneously acquired EEG activity, and subsequently averaging these location-specific visual responses across trials. Multiple posterior sites gave rise to two sizeable echo functions. Interestingly, the echo phase for a given screen location was about 10-12ms earlier on contralateral than ipsilateral electrodes. This travelling wave propagating across the scalp was highly consistent across participants (n=10). Likewise, for each posterior sensor, we found systematic phase differences between locations, such that the echo in response to the ipsilateral disc always lagged by 10–12ms relative to the echo in response to the contralateral disc. In other words, echo functions also behaved like travelling waves across the visual field, sequentially propagating from contra- to ipsi-lateral screen locations. This reveals that occipital cortex, beyond its standard encoding of retinotopic spatial dimensions, also encodes at least one more spatial dimension – but in the temporal domain, i.e. in the phase of alpha reverberations. These results constitute the first direct experimental evidence for Pitts & McCulloch's (1947) scanning hypothesis: "the alpha rhythm performs a temporal 'scanning' of the cortex which thereby gains, at the cost of time, the equivalent of another spatial dimension in its neural manifold".

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56.4039 **Reduced steady-state following responses in primary visual cortex in an animal model of schizophrenia** Alexander Schielke[1,2](alexander.schielke.mail@gmail.com), Bart Krekelberg[1]; [1]Center for Molecular and Behavioral Neuroscience, Rutgers University, Newark, NJ 07102, USA, [2]Behavioral and Neural Sciences Graduate Program, Center for Molecular and Behavioral Neuroscience, Rutgers University, Newark, NJ 07102, USA

Schizophrenia (Sz) is a severe and disabling brain disorder that affects approximately 1% of the population. Even though the psychotic symptoms of schizophrenia are better known, patients display significant changes in visual processing and perception; these are stable throughout the course of the disease, better prodromal indicators of disease progression than many traditional neuropsychological tests, and thought to be related to aberrant neural dynamics in visual cortex. Specifically, we investigated the synchronization of cortical responses to the repetition rate of photic stimulation. In comparison to healthy subjects, patients with Sz show reduced power of steady state visually evoked potentials (SSVEP) at the stimulation frequency when the repetition rate is within the beta or gamma range. We hypothesized that hypofunction of the NMDA receptor – one of the neurotransmitter systems implicated in Sz – could underlie this phenomenon. To test this hypothesis, we injected two rhesus monkeys (m. mulatta) either with sub anesthetic doses of the NMDA-receptor antagonist ketamine (0.3mg/kg), or with saline (control). After the injection we presented whole-screen flicker at temporal frequencies of 0, 5, 11, 23, or 47 Hz and recorded evoked local field potentials using permanently implanted multi-electrode arrays in area V1. The SSVEP was assessed by determining the power at the visual stimulation frequency. Ketamine injections resulted in a reduction of the SSVEP. This finding was consistent across recording sites and sessions. Similar to the findings in patients with Sz, the largest SSVEP reductions were found for photic stimulation at 23 Hz (beta) and 47 Hz (gamma). Our findings support the view that NMDA hypofunction could underlie visual/cognitive deficits in Sz. In addition, these results show that visual processing in the macaque can be a fruitful model to investigate cellular mechanisms of schizophrenia.

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56.4040 **Temporal Summation and Adaptation in Human Visual Cortex** Jingyang Zhou[1](jyz205@nyu.edu), Noah Benson[1], Kendrick Kay[2], Jonathan Winawer[1]; [1]Department of Psychology, New York University, [2]Department of Radiology, University of Minnesota

INTRODUCTION. Neuroimaging studies have characterized human visual cortex and subcortical nuclei using population receptive field ('pRF') models. This approach captures systematic visual properties such as scaling of spatial summation (pRF size) with eccentricity. Here, we extend pRF models to the temporal domain, building models that describe how temporally modulated stimuli relate to fMRI signals. METHODS. In each trial, subjects viewed a large-field contrast image either as a single pulse of variable duration (17-533 ms), or as two pulses (133 ms each) separated by variable duration (17-533 ms). Our temporal pRF model comprised a linear term (stimulus time-course convolved with an impulse response function) and a normalization term (linear term after low-pass temporal filtering). We divide the linear term by the normalization term and convolve the result with a hemodynamic response function ('HRF') to predict the fMRI signal. The linear and normalization terms are fitted to each visual area. We interpret the two terms as capturing temporal summation and temporal adaptation, respectively. RESULTS. The model provided excellent fits: cross-validated predictions explained 70% (temporal-occipital maps) to 97% (V1–V3) of the variance in response amplitudes across stimuli. Temporal summation length was shorter in V1 (time to peak, ~20 ms) than V3 or hV4 (~50-90 ms), whereas the temporal extent of normalization did not differ systematically between maps. Model fits to the fMRI data were also used to generate predictions at the millisecond scale (omitting convolution with the HRF); these predictions were in good qualitative agreement to time-varying broadband potentials measured by human electrocorticography in a separate dataset. CONCLUSION. We extended the pRF approach from space to time, accurately predicting responses across visual areas to stimuli with a range of temporal profiles. The increasing length of temporal summation in extrastriate maps compared to V1 parallels the increasing size of spatial receptive fields.

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Face Perception: Mechanisms and models 2

Tuesday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4041 **Auditory face identification activates selective areas within the ventral visual stream in congenitally blind** Roni Arbel-Yaffe[1](rooniarbel@gmail.com), Amir Amedi[1,2]; [1]Department of Medical Neurobiology, Institute for Medical Research Israel-Canada (IMRIC), Faculty of Medicine, The Hebrew University of Jerusalem, Israel, [2]The Edmond and Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Israel

Our remarked ability to identify faces is mediated by a specialized neural network comprising of visual as well as limbic and prefrontal regions. The Fusiform Face Area (FFA) is a key region in this network, showing consistent stronger response to visual faces than to non-face visual stimuli. Evidence collected over the years suggests that face selectivity in the FFA becomes more pronounced during childhood along with increased face identification proficiency. However it is unknown whether visual exposure is necessary for the development of this selectivity. Visual-to-Auditory Sensory Substitution Devices (SSD) convey information that is usually perceived visually via the auditory modality in a shape preserving manner, thus can be used in the investigation of face perception in the absent of sight. Using the EyeMusic Visual-to-Auditory SSD that encodes color information as well as information regarding shape, we developed a training program designed to teach blind persons the identification of colorful cartoon faces. 8 congenitally blind participants that took part in the program were able to correctly identify the faces, tell apart up-right from inverted orientation, and discriminate familiar faces from un-familiar faces. In order to identify the neural mechanism mediating auditory identification of faces we conducted an fMRI experiment that included auditory stimuli of faces from 4 categories: familiar faces, inverted faces, unfamiliar faces, and scrambled faces. Using a region-of-interest analysis we show selective activation to faces compared with scrambled faces in the left FFA. Whole-brain analysis shows selective response to faces in the bilateral ventral visual cortex. Our results suggest that face selectivity in the ventral visual stream develops without visual exposure. Additionally, while considered a visual area, our results suggest that FFA responds to facial stimuli conveyed via the auditory modality as well.

56.4042 **NEURAL BASIS AND DYNAMICS OF FACE AND VOICE INTEGRATION OF EMOTION EXPRESSION** Jodie Davies-Thompson[1](davies.jodie@gmail.com), Giulia V. Elli[2], Mohamed Rezk[1], Stefania Benetti[1], Markus van Ackeren[1], Olivier Collignon[1,3]; [1]Crossmodal Perception and Plasticity Laboratory, Center of Mind/Brain Sciences, University of Trento, Italy, [2]Department of Psychological & Brain Sciences, John Hopkins University, Baltimore, USA, [3]Institute of research in Psychology (IPSY), Institute of Neuroscience (IoNS), University of Louvain (UcL)

Background and objective: The brain has separate specialized units to process faces and voices located in occipital and temporal cortices, respectively. However, humans seamlessly integrate signals from the face and the voice of others for optimal social interaction. How does redundant information delivered by faces and voices, like emotion expressions, is integrated in the brain? We characterized the neural basis of face-voice integration, with a specific emphasis on how face or voice selective regions interact with multisensory regions, and how emotional expression affects integration properties. Method: We presented 24 subjects with 500ms stimuli containing visual only, auditory only, or combined audio-visual information, which varied in expression (neutral, fearful). We specifically searched for regions responding more to bimodal than to unimodal stimuli, as well as examining the response in face- and voice- selective regions of interest, as defined by independent localizer scans. Finally, regions of interest were entered into dynamic causal modeling (DCM) in order to determine, using Bayesian model selection methods, the direction of information flow between these regions. Results: Using a whole-brain approach, we found that only the right posterior STS responded more to bimodal stimuli than to face or voice alone when the stimuli contained emotional (fearful) expression. No regions responded more to bimodal than unimodal neutral stimuli. Region-of-interest analysis including face- and voice-selective regions extracted from independent functional localizers similarly revealed multisensory integration in the face-selective right posterior STS only. DCM analysis revealed that the right STS receives unidirectional information from the face-selective fusiform face area (FFA), and voice-selective middle temporal gyrus (MTG), with emotional expression affecting their connections strength. Conclusion: Our study promotes a hierarchical model of integration of face and voice signal with a convergence zone in the right STS and that such integration depends on the (emotional) salience of the stimuli

56.4043 **Voxel-wise tuning for retinal and face space in the occipital face area** Benjamin de Haas[1,2,3](benjamindehaas@gmail.com), Martin Sereno[1,2,4,5], D. Samuel Schwarzkopf[1,2,3]; [1]Experimental Psychology, University College London, [2]Birkbeck-UCL Centre for Neuroimaging (BUCNI), University College London, [3]Institute of Cognitive Neuroscience, University College London, [4]Cognitive Science Department, University of California, San Diego, [5]Psychological Sciences, Birkbeck College, University of London

We previously proposed that retinotopic and face part tuning in the occipital face area (OFA) interact (de Haas et al., 2014). Other recent work indicates OFA might contain a map for face parts (Henriksson et al., 2015) and voxels in OFA have Gaussian retinotopic tuning (Kay et al. 2015). Here, we present fMRI data demonstrating that voxels in OFA show Gaussian tuning for retinal as well as face space, and that both types of tuning interact. Five healthy participants underwent 4 types of mapping: During Retinal Eye and Mouth scans, bar-type mapping stimuli swept up and down the central visual field. Bars contained the eye and mouth portion of a face, respectively. During Face Up and Down scans, bar-type stimuli were shown at fixed retinal locations in the upper or lower visual field. Their content swept vertically through 'face space', showing face parts ranging from chin to hairline. Eyetracking data confirmed good fixation stability for all conditions. We fitted separate Gaussian encoding models to evoked time-series from each of the four conditions. Preliminary analyses indicate that, across participants, 3046 vertices in OFA (extending to posterior fusiform) showed retinal position tuning for eye and mouth stimuli. Peak parameters were highly reliable across both types of stimuli ($r=.89$, $p< .0001$), but slightly shifted upwards for eye vs. mouth stimuli ($t=13.31$, $p< .0001$). 354 vertices showed face space tuning that was reliable across retinal positions ($r=.57$, $p< .0001$), but shifted towards eyes for stimuli in the upper visual field ($t=3.00$, $p=.003$). Face tuning in the right hemisphere ($n=114$) peaked mostly around the eye region, whereas left hemisphere peaks included lower face parts (position difference $t=12.74$, $p< .0001$; dispersion difference: $W^*>5$, $p< .0001$). These results indicate that retinal and face tuning interact and that face part selectivity differs between hemispheres.

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56.4044 **Distributed information processing across OFA and FFA represents individual face identities** Yuanning Li[1,2,3](ynli@cmu.edu), Avniel Ghuman[1,2,3]; [1]Program in Neural Computation, Carnegie Mellon University and University of Pittsburgh, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University and University of Pittsburgh, [3]Department of Neurological Surgery, School of Medicine, University of Pittsburgh

In contrast to traditional hierarchical models, most current models of visual perception suggest that distributed networks of regions across the visual processing stream underlie visual recognition. For example, multiple face patches, including the occipital face area (OFA) and the fusiform face area (FFA) likely work in concert to encode individual faces. However, direct evidence for distributed computation of individual faces does not exist because to date no methods exist to examine the information represented in neural interactions. Here we develop a novel pattern recognition method, called Multi-Connection Pattern Analysis (MCPA), to extract the discriminant information about cognitive conditions solely from the shared activity between two neural populations. In MCPA, functional connectivity models are built based on shared multivariate neural activity using canonical correlation analysis for each condition. Then using these models the activity in one area is predicted solely based on the activity in the other area for each condition. Classification is achieved by comparing the predicted activity with the true activity, revealing the representational structure of the shared neural activity (e.g. the information represented in the functional interaction). MCPA was applied to analyze intracranial EEG (iEEG) data recorded simultaneously from OFA and FFA in a human subject. Our results support the hypothesis that individual-level face information is not only encoded by the population activity within certain brain populations, but also represented through recurrent interactions between multiple distributed populations at the network level. In addition, the critical time window for face individuation based on MCPA was approximately 200 – 500 ms after stimulus onset, which is consistent with our previous study based on iEEG recording from FFA only. This suggests the involvement of FFA in the face individuation process is a result of temporally synchronized, recurrent interactions between FFA and other nodes in the face-processing network, including the OFA.

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56.4045 **The right FFA is functionally connected to the dorsal visual pathway during configural face processing.** Valentinos Zachariou[1](zachariouv@mail.nih.gov), Stephen Gotts[1], Zaid Safiullah[1], Leslie Ungerleider[1]; [1]Laboratory of Brain and Cognition, NIMH/NIH, Bethesda, MD

Configural processing, the processing of the spatial relationships among the features of a face, is a vital component of face perception. If configural processing depends on spatial information, might this process involve interactions between the face-processing regions of the ventral stream and visuospatial processing regions of the dorsal stream? We explored this question in healthy adults by examining the pattern of functional connectivity between the right FFA as a seed (individually defined) and the rest of the brain in a same-different face detection task. Detection of configural relative to featural face differences led to significantly stronger functional connectivity between the right FFA and a-priori localized spatial processing regions of the dorsal stream. In contrast, detection of featural relative to configural face differences led to stronger functional connectivity between the right FFA and other face-processing regions of the ventral stream, such as the right OFA and left FFA, as well as with the insula bilaterally. Further, these connectivity patterns correlated positively with reaction time performance: participants that responded slower on configural difference trials showed stronger functional connectivity between the right FFA, the left FFA and OFA and a-priori localized spatial processing regions of the dorsal stream, particularly within the left posterior parietal cortex. Conversely, participants that responded slower on featural difference trials showed stronger functional connectivity between the right FFA and anterior regions of the right inferior temporal gyrus, left insula and bilateral inferior frontal gyrus. Together, the findings suggest that the right FFA interacts with spatial processing regions of the dorsal stream during configural face processing and with ventral stream face-processing regions during featural face processing. Additionally, the extent of these interactions appears to depend on task demands.

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56.4046 Facial identity encoding, face space structure and neural-based image reconstruction in congenital prosopagnosia. Dan Nemrodov[1](dannem@gmail.com), Adrian Nestor[1], Galia Avidan[2], David Plaut[3,4], Marlene Behrmann[3,4]; [1]Department of Psychology at Scarborough, University of Toronto, [2]Department of Psychology, Ben-Gurion University of the Negev, [3]Department of Psychology, Carnegie Mellon University, [4]Center for the Neural Basis of Cognition, Carnegie Mellon University

The neural correlates of facial recognition deficits in congenital prosopagnosia (CP) have been extensively researched and debated. Here, we investigate the neural basis of face identification in two CP individuals with the aid of pattern analysis applied to a comprehensive set of neuroimaging (fMRI) and behavioral data. To this end, first, we employ information-based mapping to localize cortical regions able to support identity discrimination in these individuals. Second, we use behavioral and neural-based confusability matrices derived from activation patterns in such regions to estimate the structure and properties of individual-specific face space. And last, we exploit the resulting face space estimates for the purpose of facial image reconstruction separately from behavioral and neural data. Our results indicate that: (i) facial identity encoding in CP relies on a cortical network comparable to that found in normal controls but the magnitude of pattern discrimination appears to be comparatively lower in specific regions; (ii) the structure of face space in CP can be recovered from behavioral and neural data (but less robustly estimated than in the normal population); and (iii) this structure supports above-chance image reconstruction results thus helping to visualize face percepts in a visually impaired population. In summary, the present findings shed new light on the neural profile of visual face encoding in CP while they also showcase the benefit of new methodological tools (e.g., image reconstruction) in elucidating the nature and the specifics of high-level visual representations.

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56.4047 Dynamic flow of Face Categorization Task Information in an MEG Network. N. Rijsbergen[1](nicola@psy.gla.ac.uk), R. Ince[1], G. Rousselet[1], J. Gross[1], P. Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow

To categorize faces by their gender and expression, the brain combines task specific visual information with conceptual information about the target categories. In the hierarchical architecture of the early visual brain, the input face undergoes a complex integration of information gathered from independently processed contralateral visual fields. How does information integration interact with the demands of multiple categorization tasks? Here, three observers categorized by gender (2-AFC) and expression (7-AFC, expressions of emotion plus 'neutral') the same male and female expressive faces while we measured observers' single-trial MEG responses. On each of the 20,000 trials per task, with Bubbles (Gosselin & Schyns, 2001) we randomly sampled pixels from the original faces using Gaussian apertures distributed across 5 one-octave Spatial Frequency bands. With Information Theoretic measures (Mutual Information) applied to uni- and multi-variate reverse correlation analyses (Ince et al. 2015), we first computed the different face pixels associated with behavior in each categorization task. Then, applying the same analyses to each voxel of MEG time series, we reconstructed the dynamic processing flow of task-relevant face pixels in the brain (Task Information, S1, one observer) and we further analyzed the flow of the task-specific features in the MEG voxels (Left vs. Right Face Information, S1). In the reconstructed information categorization task and feature information flows, we reveal a common process of visual hemifield integration whereby left and right occipito-temporal regions initially (100-150ms post stimulus) code face features from the contra-lateral visual hemifield, followed, primarily in one hemisphere (left in S1), by a period of bilateral face coding when face features are categorization dependent and integrated. Following integration, visual and task information spatially and temporally dissociate. The occipito-temporal regions keep coding of task-related face features whereas the categorization task itself shows a secondary parietal peak at 250-300ms.

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56.4048 Watching the brain recalibrate: An ERP correlate of renormalization during face adaptation Nadine Kloth[1,2](nadine.kloth@icloud.com), Gillian Rhodes[1,2], Stefan Schweinberger[1,2,3]; [1]ARC Centre of Excellence in Cognition and its Disorders, School of Psychology, The University of Western Australia, [2]DFG Research Unit Person Perception, Friedrich Schiller University of Jena, Germany, [3]Department of Psychology, Friedrich Schiller University of Jena, Germany

The face perception system flexibly adjusts its neural responses to current face exposure, inducing aftereffects in the perception of subsequent faces. For instance, adaptation to expanded faces biases observers to perceive undistorted faces as compressed, and adaptation to compressed faces induces biases to perceive undistorted faces as expanded. Such distortion aftereffects have been proposed to result from renormalisation, in which the face perception system defines recent face characteristics as "normal" and evaluates subsequent faces relative to that. However, although consequences of adaptation are easily observed in behavioural aftereffects, it has proven difficult to observe renormalisation during adaptation itself. Here, we establish the occipitotemporal P2 ERP as an electrophysiological indicator of renormalisation. Participants adapted to sequences of four consecutive compressed, undistorted, or expanded faces with different identities, followed by a slightly compressed or expanded test face, which participants had to classify as undistorted or distorted. Unlike earlier studies, we analyzed not only the ERPs evoked by the test faces, but also by each of the four adaptors. We found that the P2 amplitudes evoked by consecutive adaptor faces exhibited an electrophysiological pattern of renormalisation during adaptation: P2 amplitudes evoked by both compressed and expanded adaptors significantly increased as adaptation proceeded: P2 amplitudes were consistently smallest for the first adaptor and significantly larger for both the second and third adaptor. Replicating earlier research, larger P2 amplitudes were also evoked by test faces for which adaptation had increased perceived normality. Specifically, after adaptation to expanded faces, P2 amplitudes were larger for expanded than compressed test faces. After adaptation to compressed faces, P2 amplitudes were larger for compressed than expanded test faces. We conclude that the sensitivity of the occipitotemporal P2 to the perceived deviation of a face from the current norm makes the component an excellent tool to demonstrate and study adaptation-induced renormalisation.

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56.4049 Neural representations of visual stimuli are influenced by cognitive load Luca Vizioli[1](lvizioli@umn.edu), Kendrick Kay[1], Junpeng Lao[2], Meike Ramon[2]; [1]Center for Magnetic Resonance Research (CMRR), University of Minnesota, [2]Department of Psychology, University of Fribourg

Understanding how humans form a coherent percept of the visual word represents a major endeavor for cognitive and vision scientists alike. Variations in task demands elicit different neural representations of identical visual input. However, it remains unclear how and where in the brain external and internal inputs interact. To address this fundamental question, we recorded the BOLD signal (whole brain scan; TR=2s; voxel size=2-mm isotropic) of 10 participants during different tasks with identical visual stimuli. In a fast, event-related experiment, participants viewed images of personally familiar faces or edible objects while performing either an identity task or a category-membership (fe/male, fruit/vegetable) decision task. Importantly, we manipulated the spatial frequency (SF) content by parametrically varying the amount of low-pass filtering to simulate the information available at different viewing distances, thereby controlling cognitive load. We compared the performance of three models in predicting the beta weights elicited by each stimulus under different task constraints across the whole brain. Model 1 was a monotonic function of SF level (i.e., bottom-up model); model 2 was a nonlinear combination of the same monotonic SF level function and participants' RT (representing a proxy of cognitive load); and model 3 was a nonlinear combination of the monotonic SF level function, participants' RT and accuracy scores (representing a proxy of the information required to fulfill the task). Our data shows that, behaviorally, RT and SF information requirements varied across tasks. Crucially these differences drive neural response accordingly: cognitive load and task-dependent information requirements increased model accuracy in parietal and ventral cortices (specifically in the FFA for face tasks). These results confirm that neural activation elicited by identical retinal inputs is not invariant, but shaped by top down task constraints. Specifically, we posit that cognitive load plays a crucial role in influencing neural representations.

56.4050 Automatic contribution of colour information to face categorization from briefly presented natural images
Charles C.-F. Or[1](charles.or@uclouvain.be), Talia Retter[1,2], Bruno Rossion[1]; [1]Psychological Sciences Research Institute & Institute of Neuroscience, University of Louvain, Belgium, [2]Department of Psychology, University of Nevada, Reno, USA

The contribution of colour to rapid categorization of natural images is debated. Here, the effect of colour on face categorization was examined using a recently validated paradigm (fast periodic visual stimulation) for measuring high-level face categorization responses with natural images (Rossion et al., 2015, J Vis). High-density electroencephalogram (EEG) was recorded during presentations of 50-s sequences of object images sinusoidally contrast-modulated at F = 12.0 Hz (i.e., 83-ms stimulus-onset asynchrony). Face images were embedded in the sequence at a fixed interval of F/9 (1.33 Hz). There were four conditions: 1) full-colour images; 2) greyscale images; 3) and 4) phase-scrambled images from Conditions 1 and 2, respectively, making faces and objects unrecognizable. Observers' task differed across two experiments: 20 observers responded to random colour changes of a fixation cross ("colour task"); another 20 observers responded when the fixation cross changed to a square ("shape task"). In both experiments, with natural images, selective responses to faces were recorded at 1.33 Hz and harmonics (2.67 Hz, etc.) over occipito-temporal areas, with right-hemisphere dominance; this response was absent with scrambled images. Importantly, in the shape task, face-categorization response (sum of all-channel-averaged responses at significant harmonics) was 22% stronger with natural images in colour than in greyscale ($p = 0.025$), indicating a substantial advantage from image colour information; this colour advantage was not significant in the colour task ($p = 0.94$). Behavioural analysis revealed that observers performing the colour task responded 20 ms slower when the natural images contained colour ($p = 0.023$), despite hit rates at ceiling (> 95% correct) in all conditions. However, no such response-time differences were found in the shape task ($p = 0.71$). Thus, the advantage of image colour to face categorization interacts with behaviour, suggesting that colour, when not a distractor, has an automatic contribution to face categorization in natural images.

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56.4051 At a single glance: uncovering the magnitude and spatio-temporal dynamics of neural face categorization responses with rapid streams of natural images
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Perceptual categorization, the fundamental process by which sensory events are differentiated and organized, occurs extremely rapidly under natural viewing conditions. Yet, despite a wealth of research in human vision, category-selective responses to single-glanced, natural (i.e., unsegmented) images in a perceptually continuous presentation stream have not been identified and characterized in terms of magnitude and spatio-temporal dynamics. We presented 16 human observers with variable natural images of objects at a fast periodic rate of 12.5 Hz, i.e., every 80 ms. Variable natural face images were inserted every 3, 5, 7, 9, or 11 stimuli, defining face stimulus-onset-asynchrony (SOA) conditions from 240 to 880 ms, i.e., face presentation frequencies (Fs) from 4.17 to 1.14 Hz (e.g., for the 240 ms face SOA, F = 1/0.24 s = 4.17 Hz). After just a few minutes of stimulation, face-selective responses were objectively identified at F for every condition in the frequency domain of the high-density electroencephalogram (EEG, 128 channels). Additional harmonic-frequency responses (i.e., 2F, 3F, etc.) were distributed and characterized within a common frequency range across conditions, providing novel evidence that baseline-corrected harmonic responses should be summed for quantification. Thus, the magnitude of the face-selective response was revealed to be stable across conditions; however, for the lowest 240 ms face SOA, the response was significantly reduced by 25% over three maximal right occipito-temporal channels. Correspondingly, only face SOAs above 240 ms revealed four successive face-selective response components, emerging from about 100 ms post-stimulus onset and progressing from posterior to occipito-temporal electrode sites until about 550 ms. Uncovering category-selectivity in a rapid stream of single-glanced natural images and characterizing its spatio-temporal dynamics goes well beyond previous evidence obtained from spatially and temporally isolated stimuli, opening an avenue for increasing our understanding of human vision, including its neural basis and relationship to visual categorization behavior.

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56.4052 Tilt aftereffects in face space
O. Gwinn[1](ogwinn@unr.edu), Michael Webster[1]; [1]Department of Psychology, University of Nevada, Reno

Models of face coding often assume "opponent" representations in which opposite faces are represented by opposite responses relative to a norm. The norm could be implicit (e.g. equal activity in channels tuned to opposing directions) or explicit (e.g. a null in a single mechanism that responds oppositely to opposing directions, similar to color opponency). Most studies of face aftereffects fail to distinguish between these alternatives because they adapt to a single face. We examined adaptation to sequences of faces that randomly varied over time along one direction but with a fixed mean centered on the norm. Faces were distorted by local expansion or contraction along the vertical (90-270 deg) or horizontal (0-180 deg) axes. Observers were adapted to one axis in the left visual field and the orthogonal axis in the right. They then adjusted the angle of a test face using a staircase until the vertical and horizontal distortions appeared equal (i.e. angles of 45 or 225 deg). Adaptation to each orientation biased the test faces away from the adapting axis – analogous to a tilt-aftereffect within the space. The two test poles rotated in the same way (e.g. clockwise), arguing against a mean bias. Distortion aftereffects for a single face tend to be uniform across the space, suggesting that the tilts are also unlikely to reflect locally stronger biases from more nearby adaptors. Instead, the aftereffects could reflect a loss in contrast sensitivity, and thus adaptation at an explicit opponent site. This contrast adaptation provides an alternative explanation for contingent face-aftereffects, in which opposing aftereffects occur in faces paired with opposing features. These are typically interpreted in terms of separate norms for different face categories, but could also reflect tilt-aftereffects relative to a single norm.

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56.4053 Does differential shape-contour processing precede or follow category-selective processing?
Juliet Shafto[1](jshafto@andrew.cmu.edu), Michael Tarr[1]; [1]Carnegie Mellon University

Numerous regions along the ventral visual stream have selective responses to particular categories of stimuli. However, it has not been established what types of low- and mid-level visual properties contribute to the emergence of high-level category selectivity during processing. One dimension that has been posited to play a role is the curvilinearity/rectilinearity of shape contours: fMRI studies have found that face-selective areas respond preferentially to curvilinear shapes while place-selective areas respond preferentially to rectilinear shapes. Unknown, however, is whether the dissociation of curved and rectilinear contours precedes or follows category-selective responses. In particular, does the separable processing of faces and scenes rely, at least in part, on differences in shape contours? Alternatively, is shape-contour sensitivity an epiphenomenal consequence of already divergent processing of faces and scenes? To address this question, we recorded event-related potentials during a simple luminance-change detection task while participants viewed a series of images of matched novel curvilinear and rectilinear patterns, as well as faces, scenes, and objects. We observed that curvilinear and rectilinear shape contours give rise to dissociable signals at lateral-occipital electrode sites. However, the signals temporarily diverged after the initial separation of face and scene ERP components. This finding suggests that the presence of differing shape-contours is not the basis for the initial segregation of faces and scenes in visual processing.

56.4054 Testing the independence of neural representations of face identity and expression through multidimensional signal detection theory
Fabian Soto[1](fabian.soto@fiu.edu), Lauren Vucovich[2], F. Greg Ashby[2]; [1]Department of Psychology, Florida International University, [2]Department of Psychological & Brain Sciences, University of California, Santa Barbara

Many research questions in visual perception–particularly those dealing with notions such as "independence," "invariance," and "holism" of visual representations–are special cases of the problem of perceptual separability. In visual neuroscience, there is great interest in determining to what extent important object dimensions are represented separately in the brain. However, progress in the study of separability has been hindered by inadequate

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methods for its detection. In particular, the definitions of independent or separable representations used in most published research are operational, lacking a theory to guide the interpretation of results. Here we describe a new test of perceptual separability for fMRI data, based on a theoretical definition from multidimensional signal detection theory. The test is essentially an extension to multi-voxel pattern analyses: a linear classifier is used to classify activity patterns related to individual stimulus presentations on the basis of a specific stimulus dimension (e.g., "sad" vs. "neutral" faces). The data points are then projected to a line orthogonal to the classification bound (i.e., the "emotion" dimension) and used to estimate a probabilistic perceptual distribution for each stimulus, as proposed by signal detection theory. These estimated perceptual distributions can be used to directly assess perceptual separability. This test has a strong theoretical basis and can be related to behavioral tests of separability that have been widely applied in the past. We apply the test to the study of separability of human face identity and emotional expression. Twenty-one participants completed a face identification task with faces varying in identity and emotional expression (neutral/sad). fMRI data was analyzed using the new separability test. Violations of separability were present for both emotional expression and identity, they were widespread across areas in the face network, and they were more prevalent in the left hemisphere.

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56.4055 **Observers perceive the average identity of amodally completed faces** Lauren Ulrich[1](ulrlm-16@rhodes.edu), Jason Haberman[1]; [1]Rhodes College

Faces are thought to be processed holistically, as opposed to through a piecemeal, part-by-part synthesis. This process is so robust that partially occluded faces (e.g., amodally complete behind bars) are nonetheless easy to recognize. This suggests that face recognition may operate despite incomplete visual information (i.e., conceptual representations). Here, we explored whether observers could derive high-level ensemble representations, that is, summary statistical representations, from sets of amodally completing faces. Observers viewed sets of faces varying in identity and adjusted a test face to match the perceived average identity. Faces were linearly interpolated morphs across three identities. The whole set comprised 360 images forming a 'face wheel.' In one condition, the faces amodally completed behind black, horizontal bars. In another condition, the identical facial information was presented, but in the foreground (i.e., the face parts appeared on three-dimensional, fragmented strips in front of a black background). Baseline performance was determined by having observers view and adjust the original, un-occluded faces. The results revealed that the ensemble representation of amodally completing sets was significantly better than the fragmented sets and was not significantly different than the baseline condition. This suggests that high-level face ensembles may be represented conceptually, but that this representation is best when the faces amodally complete.

Face Perception: Disorders

Tuesday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4056 **Alzheimer's disease: temporal and familiarity gradients in face recognition.** Marie-Christine Nizzi[1,2](marie.nizzi@gmail.com), Christine Moroni[2], Ken Nakayama[1]; [1]Harvard University, Psychology Department 33 Kirkland Street, Cambridge, MA 02138 (USA), [2]Univ. Lille, EA 4072 PSITEC - Psychologie: Interactions, Temps, Émotions, Cognition F-59000 Lille, France

Introduction: An extended literature has documented the impairment of face recognition in Alzheimer's disease (AD). However, standardized face-recognition tasks focus on celebrities when the real life issue is to understand when and how patients stop recognizing their loved-ones and themselves. We suggest that testing for various degrees of familiarity (self, spouse, family members and celebrities) might shed light on how face recognition deteriorates in AD. Furthermore, previous studies have hinted at a temporal gradient in AD: old episodes or photographs are better recognized than recent ones (Hehman et al., 2005). Therefore, our stimuli will span across 4 decades (1980, 1990, 2000, 2010). Methods: 5 AD patients and 6 matched controls were asked to identify 48 faces from four decades, including 8 pictures of the participant, 8 pictures of their spouse and family members, 8 celebrities, and 24 perceptually matched foils. Celebrities were preselected based on >80% successful recognition in healthy age matched subjects. Results: Patients differed significantly from controls in accuracy and response time. In terms of temporal gradient, the performance of AD patients dropped significantly compared to controls for the 3 most recent decades, suggesting a measurable impairment starting around the time of initial brain deterioration. As for familiarity, patients differed significantly from controls in each category. More importantly, patients' performance was significantly worse for more remote others than for close others (self and spouse better than family and celebrities, $p< 0.001$; self, spouse and family better than celebrities, $p=0.007$; and spouse, family better than celebrities, $p=0.02$) whereas controls showed no such difference. This suggests that the impairment of face recognition in AD affects remote others more than it affects close others. A larger sample is needed to determine if this effect follows cognitive decline, i.e. if the close others are gradually less recognized as the dementia progresses.

56.4057 **Topographic disorientation (TD) in Developmental and Aquired Prosopagnosia patients** Jeffrey Corrow[1], Sherryse Corrow[1], Edison Lee[1], Ford Burles[2], Bradley Duchaine[3], Giuseppe Iaria[2], Jason Barton[1]; [1]Human Vision and Eye Movement Laboratory, Departments of Medicine (Neurology), Ophthalmology and Visual Science, University of British Columbia, Vancouver, Canada, [2]University of Calgary, Psychology, [3]Dartmouth College, Psychological and Brain Sciences

Previous studies report that acquired prosopagnosia is frequently associated with topographic disorientation. However, whether this is associated with a specific anatomic subtype of prosopagnosia, how frequently it is seen with the developmental variant of this disorder, and what specific topographic function is impaired to account for this problem are not known. We studied ten subjects with acquired prosopagnosia from either occipitotemporal or anterior temporal lesions and seven with developmental prosopagnosia. Subjects were given a battery of topographic tests, including house and scene recognition, the road map test, a test of path integration from optic flow, and cognitive map formation and use. House and/or scene recognition were frequently impaired after either occipitotemporal or anterior temporal lesions in acquired prosopagnosia. Subjects with occipitotemporal lesions were also impaired in cognitive map formation: an overlap lesion analysis identified right fusiform and parahippocampal gyri as a likely correlate of this deficit. Path integration was intact in all and only one subject with acquired prosopagnosia had mild difficulty with directional orientation on the road map test. Only one subject with developmental prosopagnosia had difficulty with cognitive map formation, and none were impaired on the other tests. We conclude that topographic disorientation in acquired prosopagnosia reflects impaired place recognition, with a contribution from poor cognitive map formation when there is occipitotemporal damage. Topographic impairments are less frequent in developmental prosopagnosia.

Acknowledgement: CIHR, NSERC, and NIH

56.4058 **Tone deafness in developmental prosopagnosia - is there a common cause?** Sherryse Corrow[1](sherryse.corrow@icloud.com), Jacob Stubbs[1], Stephanie Buss[2], H. Charles Li[2], Gottfried Schlaug[2], Jason Barton[1]; [1]Neurology/Ophthalmology and Visual Sciences, Faculty of Medicine, University of British Columbia, [2]Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School

OBJECTIVE: Developmental prosopagnosia is a disorder of face recognition. Recent work has shown differences between those with prosopagnosia and controls in matter connectivity of the inferior longitudinal fasciculus. Amusia is another developmental disorder which has been shown to have grey matter abnormalities in non-primary perisylvian regions and is associated with white matter connectivity in the arcuate fasciculus (Loui et al, 2009). Based on anecdotal reports of some subjects, we hypothesized that there may be instances in which these two disorders overlap. METHOD: Eight subjects with prosopagnosia were compared to healthy controls on three measures. The Montreal Battery of Evaluation of Amusia examined melodic organization, temporal organization, and memory. Subjects also completed pitch discrimination and beat perceptual threshold tasks (Loui et al., 2009; Fujii & Schlaug, 2014). RESULTS: On the Montreal Battery of Evaluation of Amusia, the prosopagnosic sample was impaired relative to normative data on their overall score [$p< 0.01$] as well as pitch interval perception [$p< 0.0001$]. At the individual level, 3 subjects were impaired on scale (1), contour (2), interval (3), meter (1), and memory (1). While the prosopagnosia group was not impaired on the pitch discrimination task, there was a group difference on the rhythm perception task and 4 of the subjects with prosopagnosia performed at least 2 s.d. outside of the control mean. DISCUSSION: At least some cases of developmental prosopagnosia also show deficits found in congenital amusia. This association could be explained by a common structural cause, such as a focal cortical migration disorder or aberrant white matter connectivity. Whether this is a primary white matter disconnection or secondary to a cortical migration disorder is not yet clear. Future work will include high resolution MRI to reveal neural substrates that are common between both disorders to determine the anatomic substrate of this behavioral observation.

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56.4059 No emotion adaptation to the low spatial frequencies of hybrid faces in developmental prosopagnosia Edwin Burns[1](eburns@ntu.edu.sg), Joel Martin[2], Alice Chan[1], Hong Xu[1]; [1]Division of Psychology, HSS, Nanyang Technological University, [2]Department of Psychology, Swansea University

Developmental prosopagnosia (DP) is characterized by an inability to recognize faces. Adapting to a stimulus for a few seconds can lead to diminished perceptions of that stimulus's characteristics in following items: for example, viewing a happy face will lead to a subsequently presented face as appearing sadder (Fox & Barton, 2007). When the coarse visual information (low spatial frequencies – LSF) from a happy face is blended with the remaining spatial frequencies of an expressionless face, these hybrid faces are rated as emotionally neutral (Laeng et al., 2010). These LSF are thought to be associated with holistic processing (Goffaux & Rossion, 2006). Here we asked a group of DP cases and neurotypical individuals (NT) to adapt to emotionally neutral faces, happy faces, or hybrid faces and rate subsequently presented test faces that had been morphed to vary from sad to happy. We hypothesized that if DP is associated with deficits in holistic processing of emotion (Palermo et al., 2011), then those with DP should exhibit no adaptation aftereffects to the hybrid faces' LSF. We found that in NT, the happy and hybrid faces produced similar emotion adaptation aftereffects relative to the neutral faces. In contrast, those with DP exhibited emotional aftereffects by adapting to the happy faces, but not the hybrid faces. These results suggest that a large amount of emotion processing in NT appears to occur outside of conscious awareness due to the holistic processing of LSF. By contrast, those with DP appear incapable of this implicit processing of emotion and instead have to identify emotional faces by their featural content alone. These findings suggest that the processing of emotion holistically, and face recognition, to some extent share a common neural pathway.

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56.4060 On the relation between face and object recognition in developmental prosopagnosia: Systematic association but no dissociation. Christian Gerlach [1](cgerlach@health.sdu.dk), Solja Klargaard[1], Randi Starrfelt[2]; [1]Department of Psychology, University of Southern Denmark, [2]Department of Psychology, University of Copenhagen, Denmark

There is an ongoing debate about whether face recognition and object recognition constitute separate cognitive domains. Clarification of this issue can have important theoretical consequences as face recognition is often used as a prime example of domain-specificity in mind and brain. An important source of input to this debate comes from studies of individuals with developmental prosopagnosia, suggesting that face recognition can be selectively impaired. We put the selectivity-hypothesis to test by assessing the performance of 10 subjects with developmental prosopagnosia on demanding tests of visual object processing involving both regular and degraded drawings. None of the individuals exhibited a dissociation between face and object recognition, and as a group they were significantly more affected by degradation of objects than control participants. Importantly, we also find positive correlations between the severity of the face recognition impairment and the degree of impaired performance with degraded objects. This suggests that the face and object deficits are systematically related rather than coincidental. We conclude that at present, there is no strong evidence in the literature on developmental prosopagnosia supporting domain-specific accounts of face recognition

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56.4061 Topographical ability in Developmental Prosopagnosia: preserved perception but impaired memory of spatial scenes Solja Klargaard[1](sklargaard@health.sdu.dk), Randi Starrfelt[2], Anders Petersen[2], Christian Gerlach[1]; [1]Department of Psychology, University of Southern Denmark, Denmark, [2]Department of Psychology, University of Copenhagen, Denmark

Anecdotal evidence suggests a relation between impaired spatial (navigational) processing and developmental prosopagnosia (DP). To address this formally, we tested nine individuals with DP and 18 matched controls on a four-choice match-to-sample test of (concurrent) topographical perception and topographical short-term memory (2 sec delay). The stimulus material consisted of computer-generated mountain landscapes shown from seven different viewpoints. In comparison with controls, the individuals with DP had no difficulty in perceiving the spatial aspects of the landscapes, but some were impaired in the short-term retention of these mountain landscapes. No systematic relationship (correlation) was found between recognition memory for faces and landscapes. Indeed, three cases with DP showed a statistically significant classical dissociation between these domains. Additional testing revealed that the deficit in topographical memory did not relate systematically to impaired visual short-term memory or recognition of more complex material. In conclusion, some individuals with DP show subtle deficits in topographical memory. Importantly, the deficits in topographical memory and face recognition do not seem to reflect the same functional impairment.

Acknowledgement: Danish Research Council for Independent Research | Humanities (grant no. DFF – 4001-00115)

56.4062 Open neuropsychology: Testing a new approach via prosopagnosia Brad Duchaine[1](bradley.c.duchaine@dartmouth.edu), Jiahui Guo[1]; [1]Psychological and Brain Sciences, Dartmouth College

Here we describe an approach that aims to enhance the impact of neuropsychological studies by using the Internet to facilitate collaboration between researchers working with neuropsychological participants and researchers with other types of expertise. Progress in neuropsychology has been limited by a traditional approach in which research participants are tested only by the laboratory that first identifies them. This practice limits advances in neuropsychology by 1) restricting the theoretical issues addressed, 2) slowing investigations, and 3) lessening opportunities for replication. We aim to replace this model with what we call Open Neuropsychology. Behavioral and neuroimaging results from participants will be posted online (www.openneuropsychology.org). The posted profiles will signal the posting lab's interest in considering collaborative proposal from other labs and allow other researchers to identify participants with profiles relevant to their research questions. The effectiveness of this approach will be investigated with a group of acquired prosopagnosics who have been tested in our lab or other labs. If this approach is successful for prosopagnosia research, we will work with neuropsychologists researching other conditions to extend it to other areas of neuropsychology.

56.4063 Gray matter differences are associated with non-identity face perception in developmental prosopagnosia Jiahui Guo[1](Jiahui.Guo.GR@dartmouth.edu), Hua Yang[1], Constantin Rezlescu[2,3], Tirta Susilo[4], Bradley Duchaine[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]Department of Psychology, Harvard University, [3]Institute of Cognitive Neuroscience, University College London, [4]School of Psychology, Victoria University of Wellington

People with developmental prosopagnosia (DP) show considerable behavioral and neural heterogeneity, but no links between behavioral and neural measures within DP have been reported. Similar to previous reports, comparison between 18 DPs and 18 controls showed DPs had reduced gray matter intensity in temporal cortex. In addition, DPs had reductions in bilateral inferior frontal cortex, bilateral amygdala, left lateral inferior occipital cortex, and right hippocampus. To examine behavioral differences within the DPs, we assessed their perception of identity, sex, age, race, anger, trustworthiness, eye position, and head viewpoint with sorting tasks. Cluster analysis of these results suggested the DPs could be divided into a group that had normal perception of sex, age, race, anger, and trustworthiness (Type I) and another with impaired perception of these aspects (Type II). Compared with Type II DPs (n = 7), Type I DPs (n = 10) had reduced gray matter intensity in the vicinity of inferior frontal gyrus bilaterally and right lateral inferior occipital cortex and increased gray matter intensity around bilateral hippocampus (uncorrected). Because of the difficulty of establishing a clear division between different types, we computed a perception index for each DP based on the five CFPT tests that differed between Type I and Type II DPs. A multiple regression analysis with the perception index and gray matter intensity found results consistent with our comparison between the two types of DP, with positive correlations for inferior frontal gyrus bilaterally and right lateral inferior occipital cortex, as well as negative correlations for hippocampus bilaterally. In summary,

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our results indicated that DPs have reduced gray matter in temporal lobe and other areas. In addition, several areas within the DP group showed an association between gray matter and non-identity face perception.

56.4064 Impaired Face and Non-face Discrimination by Developmental Prosopagnosics (DPs) Eshed Margalit[1](emargali@usc.edu), Xiaomin Yue[2], Irving Biederman[1,3]; [1]Neuroscience, University of Southern California, [2]Laboratory of Brain and Cognition, NIMH/NIH, [3]Psychology, University of Southern California

Developmental prosopagnosics (DPs) present no lesions nor have a history of compromised neural functioning. Given that their activation of face-selective cortex is normal, it is surprising that their capacity to perceptually discriminate faces and non-face objects has never been rigorously assessed. Normal discrimination of faces would suggest that the underlying deficit might not be a consequence of a poor perceptual representation but, instead, difficulty in matching a well-defined representation to stored representations in memory. If a deficit in discriminating faces is observed, is it also manifested when discriminating non-face stimuli that differ along the same underlying physical attributes as faces and to an equivalent extent as the faces? 7 DPs and 53 controls performed a match-to-sample task (Fig. 1) in which they viewed a triangular display of either three faces or three blobs (harmonics of a sphere resembling teeth). The stimulus on the top of the display was the sample and one of the two base stimuli was an exact match to the sample with the non-matching foil differing metrically from the sample. Like the faces, the blobs were smoothly sculptured in 3D and had face texture (Portilla & Simoncelli, 2000) projected onto their visible surfaces. The subject responded by pressing the arrow key on the side of matching stimulus. The similarity of the foil to the matching stimulus was scaled according to the Gabor-jet model of V1 similarity that predicts psychophysical similarity of both faces and blobs almost perfectly (Yue et al., 2012). Importantly, the scaled distributions of dissimilarities of foils to matching stimuli were almost identical for faces and blobs. DPs were slower and less accurate than controls in discriminating both faces and blobs (Fig. 2) with their deficits approximately equivalent for both faces and blobs, suggesting a general deficit in discriminating metric variations.

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56.4065 Word and face recognition deficits following posterior cerebral artery stroke: Is there a common network for the recognition of faces and words? Christina Kühn[1], Johanne Asperud Thomsen[2], Tzvetelina Delfi[3], Helle Iversen[4], Christian Gerlach[1], Randi Starrfelt[5]; [1]Department of Psychology, University of Southern Denmark, Denmark, [2]Department of Neurosurgery, Rigshospitalet, Copenhagen, Denmark, [3]Department of Diagnostics, Rigshospitalet, University of Copenhagen, Denmark, [4]Department of Neurology, Rigshospitalet, University of Copenhagen, Denmark, [5]Department of Psychology, Copenhagen University, Denmark

Recent findings have challenged the existence of category specific brain areas for perceptual processing of words and faces, suggesting the existence of a common network supporting the recognition of both. We examined the performance of patients with focal lesions in posterior cortical areas to investigate whether deficits in recognition of words and faces systematically co-occur as would be expected if both functions rely on a common cerebral network. Seven right-handed patients with unilateral brain damage following stroke in areas supplied by the posterior cerebral artery were included (four with right hemisphere damage, three with left, tested at least 1 year post stroke). We examined word and face recognition using a delayed match-to-sample paradigm using four different categories of stimuli: cropped faces, full faces, words, and cars. Reading speed and word length effects were measured in a separate reading test. Patients were compared to controls using single case statistics. Combining the results from the two experiments, two patients with right hemisphere damage showed deficits in all categories. More interestingly, of the remaining patients, one with right and two with left hemisphere damage, showed deficits for both words and faces but were unimpaired when shown the control category, cars. Two other patients, one right and one left hemisphere damaged, showed a selective deficit for faces. To summarize, in all cases with word recognition deficits, impairment in face recognition was also present. However face recognition deficits did in some cases appear selectively without deficits in word or object recognition. Overall, this study supports the existence of a bilaterally distributed network for perceptual processing of faces and words, as lesions in either hemisphere may affect both functions. More interestingly, selective deficits in face recognition may be seen following lesions to either hemisphere, suggesting that parts of this bilateral network are specific for face processing.

56.4066 Age matters, but disease does not: Comparing processing of emotional and communicational facial expressions across age and across prevalence of Parkinson's disease Dilara Derya[1](dilara@korea.ac.kr), June Kang[1], Doyoung Kwon[1], Christian Wallraven[1]; [1]Korea University

Facial expressions are one of the most important types of non-verbal communication. Although interpretation of facial expressions is usually robust, studies have shown that both age-related and disease-related factors can influence recognition accuracy. In particular, older people show deficits in recognition of negative expressions. Similarly, patients suffering from Parkinson's disease (PD) also show impairments in recognition of fear, anger, and disgust expressions. These studies so far have only focused on the basic, or "universal" expressions. Here, we were interested in investigating and comparing the effects of age and disease on facial expression processing for a wider range of both emotional and communicational expressions. For our ongoing study we recruited a total of 79 participants: 20 PD patients, 15 age-matched, older healthy controls (HC), and 44 younger healthy controls (HCS). During the experiment, participants were instructed to watch videos of 27 facial expressions performed by 6 different actors and to rate each expression based on 12 evaluative dimensions (arousal, valence, naturalness, politeness, persuasiveness, dynamic, familiarity, empathy, honesty, attractiveness, intelligence, and outgoingness) using a 7-point Likert scale. Ratings were analyzed using within-group and across-group correlations, factor analysis, and item analyses. Overall, we found that ratings of expressions were more different due to age, than due to disease-prevalence: r(PD/HC)=.756 versus r(PD/HCS)=.627, r(HC/HCS)=.640. Three out of six factors in the factor analysis were common for all groups (arousal-dynamic, familiarity-empathy, and naturalness-sincerity), showing common evaluation patterns. Confirming earlier findings of a "positivity effect", valence ratings of negative expressions were higher for both older groups (although valence ratings highly correlated within-group: all r>.919). Similarly, negative expression were perceived as more natural but less persuasive by both older groups. Overall, our results show that age-related factors play a much larger role than PD-related factors in processing of both emotional and communicational facial expressions.

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56.4067 Rapid and objective quantification of perceptual deficits in acquired prosopagnosia with fast periodic oddball stimulation Joan Liu-Shuang[1](joan.liu@uclouvain.be), Katrien Torfs[1], Bruno Rossion[1]; [1]University of Louvain, Belgium

Perceptual deficits are common in many neurological conditions, but their assessment can be hindered by various unrelated factors (e.g. attention, comprehension, motor impairments…). Hence, a method allowing for an objective, sensitive, and efficient quantification of perception without requiring explicit behavioural output would be highly valuable. In the recently developed fast periodic oddball paradigm, base stimuli appear at a fixed rate (F Hz) with oddball stimuli, differing on a dimension of interest, inserted at regular intervals (every nth stimulus, or F/n Hz; Liu-Shuang et al., 2014, Neuropsychologia, 52, 57-72). Periodic EEG responses at the F/n Hz oddball frequency and harmonics (2F/n Hz, 3F/n Hz…) reflect the perceptual discrimination between base and oddball stimuli. We tested this approach with PS, a well-described patient who is specifically impaired at face individualisation following brain damage (acquired prosopagnosia). PS was first presented with sequences of base "object" stimuli at 6 Hz with periodically interleaved oddball "face" stimuli at 1.2 Hz (every 5th stimulus; sequence structure: ObjObjObjObjFaceObjObjObjObjFace…). In line with her preserved ability to detect faces, PS showed periodic oddball responses within the normal range. However, when face identity discrimination was tested with "different" oddball face identities (B, C, D…) inserted into sequences containing a repeated "same" base face identity (A; sequence structure: AAAABAAAACAA…, Liu-Shuang et al., 2014), significant oddball responses were found in all control (young and age-matched) participants but were absent for patient PS. These observations were obtained within 8 and 12 min of recording, respectively. Overall, our findings underline the value of the fast periodic oddball paradigm as a diagnostic tool for the rapid and objective characterisation of visual discrimination in neuropsychology and difficult to test populations.

56.4068 Attention capture by faces and trains: A developmental study Allison Brennan[1](allison_brennan@sfu.ca), Elina Birmingham[2], Grace Iarocci[1]; [1]Department of Psychology, Simon Fraser University, [2]Faculty of Education, Simon Fraser University

There is evidence that faces capture attention during visual search (Langton, Law, Burton, & Schweinberger, 2008). However faces do not capture the attention of individuals with autism spectrum disorder (ASD) to the same extent (Riby, Brown, Jones, & Hanley, 2012). Whereas individuals with ASD show less preferential processing of faces, objects in which they are interested and with which they have developed expertise have been shown to capture attention (McGugin, McKeeff, Tong, & Gauthier, 2011). In an effort to understand this possible interaction between face and special interest object processing in individuals with ASD, we conducted a visual search experiment with children with ASD (ages 7-12) and compared their performance to that of their age and IQ matched peers, and adults without ASD. Participants searched for a target in an array of distractors, which included faces, trains (the most common special interest object among children with ASD), and various neutral object categories that were not of special interest (e.g., chairs, clocks, fruit). Contrary to our hypothesis that faces would capture attention to a greater extent than trains, we found that the presence of either a face or a train slowed response times relative to the neutral distractors for all participants. Why do faces and trains capture the attention of children and adults to the same extent? We explore this question with a developmental and methodological focus.

56.4069 **Emotion processing deficits in Moebius Syndrome** Savannah Lokey[1](savannah.lokey@gmail.com), Shruti Japee[2], Christopher Baker[3], Leslie Ungerleider[4]; [1]National Institute of Mental Health, [2]Laboratory of Brain and Cognition

Moebius Syndrome (MoS), a rare congenital neurological disorder, is characterized by total or partial paralysis of the VIth and VIIth cranial nerves resulting in paralysis of the face, and a lack of skeletal muscle feedback. The facial feedback hypothesis, a prominent concept in face perception, asserts that feedback from the skeletal muscle of the face alters the experience of emotion (Buck, 1980; Soussignan, 2001; Strack, Martin, & Stepper, 1988). Thus, it is possible that patients with MoS may have trouble identifying or processing emotion. Several studies have examined the ability of individuals with MoS to recognize familiar and unfamiliar faces (Calder et al., 2000; Bate et al., 2013), to experience and express emotion (Cole, 2010), and to recognize and label facial expressions (Giannini et al, 1984; Calder et al, 2000; Bogart & Matsumoto, 2010; Bate et. al, 2013). However, results from these studies have been mixed and it is thus unclear whether MoS may lead to deficits in emotion processing. One reason for the conflicting results could be that most of the studies used an emotion-labeling task, which may not have been sensitive to subtle deficits in emotion processing. Thus, in our study we used morphs of neutral to happy or fearful faces, and an emotion detection task to measure emotion perceptual thresholds for each participant. Subjects viewed fearful and happy images containing different amounts of emotion and indicated with a button press whether the image did or did not contain emotion. A one-up, three-down staircasing procedure was used to determine each participant's threshold for 79% accuracy. Results showed that individuals with MoS, as compared to healthy controls, showed a deficit in detecting emotion. These results indicate that the paralysis of and lack of feedback from the facial muscles may impair emotion perception in individuals with MoS.

56.4070 **Atypical eye gaze perception in autism spectrum disorder arises from heterogeneous perceptual mechanisms** Peter Pantelis[1](pcpantel@indiana.edu), Daniel Kennedy[1]; [1]Department of Psychological and Brain Sciences, Indiana University-Bloomington

Individuals with autism spectrum disorder (ASD) have difficulty judging where other people are looking. Gaze perception involves the integration of social cues (e.g., from the eyes of the other person) with contextual cues (e.g., the relative visual salience of locations in the shared environment). To investigate how these cues are processed and integrated, we recently developed and modeled an experimental task in which subjects judge the target of another person's gaze as this "gazer" fixates on various locations within a semi-transparent 2-dimensional surface (Pantelis & Kennedy, 2015). Here, we employ the same methodology to investigate whether and how individuals with ASD perform this gaze perception task atypically. Twenty-two adults with ASD (and 23 controls) judged where the gazer was looking within naturalistic photographs projected onto the gazed-upon surface. We derived an estimate of the extent to which each individual subject was influenced by salient features of the projected image when judging the target of gaze. For approximately half of ASD subjects, this contextual influence was atypically weak; performance among these individuals was heterogeneous in this respect. Over 660 additional trials, subjects judged where the gazer was looking within a uniform gray surface (i.e. with no projected photograph), a task involving the processing of the basic social cue absent informative context. Control subjects' judgments exhibited a bias toward a distinctive "butterfly" pattern of spatial clustering. About half of ASD subjects also tended toward this prototypical spatial bias; the other half produced idiosyncratic spatial patterns. We conclude that in typical development, eye gaze perception is informed by both context (i.e. relative visual salience) and prototypical spatial biases, but that most individuals with ASD (70-80% of those in our sample) exhibit disruption to one or both of these perceptual mechanisms. The underlying basis of atypical eye gaze perception in ASD is likely heterogeneous.

Attention: Tracking

Tuesday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4071 **Individual differences in position tracking are related to peak occipital alpha frequency** Craig Arnold[1](craig.pa.arnold@gmail.com), Matthew Belmonte[1], Christina Howard[1]; [1]Division of Psychology, Nottingham Trent University

Although position tracking has been well studied, its underlying neurophysiological mechanisms remain poorly understood. Individual differences in temporal and spatial aspects of position tracking can be exploited to elucidate such mechanisms. Individual differences in peak alpha frequency (PAF) have been linked to several cognitive tasks. Because the phase of alpha oscillations appears to predict perception of stimuli (e.g. Busch et al., 2009) it has been suggested to be the cause of periodic updating of perception. How neural oscillations contribute to sustaining attention to moving targets has not, to our knowledge, been investigated. If rhythmic processes do play a role in position updating during tracking, this may have implications for parallel/serial tracking mechanisms. We asked observers to attempt to track the position of either one or both of two discs. After a period of semi-random motion, both discs disappeared and observers indicated the final position of one target. We calculated spatial errors: the distance between the final position and the reported final positions of queried objects. We found poorer spatial precision for monitoring two targets than a single target, consistent with a resource model of position perception. On average, people tended to report slightly out of date positions, that is to say that reports exhibited perceptual lags (e.g. Howard & Holcombe, 2008). In a separate recording block we recorded observers' resting alpha activity. We assessed individuals' PAF as the greatest mode of the occipital EEG power spectrum between 8-12 Hz. We did not observe a strong relationship between PAF and perceptual lags as may be predicted from oscillation-based explanations of lags. However individuals' PAF was correlated with position report precision such that slower peak alpha was associated with greater spatial precision. We suggest a possible role for the period of alpha oscillations in determining the accumulation of spatially precise position information.

Acknowledgement: Fundacao Bial

56.4072 **Non-independence of spatial memory and position tracking** Christina Howard[1](Christina.Howard@ntu.ac.uk), Duncan Guest[1], Amanda Hornsby[1,2], Rebekah Pole[1], Paulina Nowak[1]; [1]Division of Psychology, Nottingham Trent University, [2]Department of Clinical, Educational & Health Psychology, University College London

There is a continuing debate around the role of serial processes in multiple object tracking (MOT), with some suggesting that spatial information is updated serially (Oksama & Hyönä, 2008). Spatial memory is a necessary component of serial component models. Therefore, in three experiments, we investigated the relationship between spatial memory and position tracking of moving targets. In Experiment 1, to test spatial memory, participants viewed complex patterns and then made same-different judgements. In the tracking task, participants monitored the positions of four discs amongst distractors. At the end of each trial, participants were immediately asked to report the final position of one of the targets. Memory performance of individuals, particularly under high load, was related to the precision of their spatial reports in the tracking task. It was also related to temporal lags exhibited in responses. These lags, previously reported for tracking tasks (e.g. Howard, Masom & Holcombe, 2011), indicate that responses are more similar to the recent past states of the target in the moments leading up to its disappearance than its final state. In Experiments 2 and 3, to investigate this relationship more directly, we manipulated memory load and tracking load independently under dual task conditions. In neither experiment did memory load affect tracking performance in terms of spatial precision or temporal lags. Conversely, there were detrimental effects of tracking load on memory. Modelled memory capacity estimates were very poor at just over one object in Experiment 2 and under one object in Experiment 3.

These results indicate an asymmetric relationship whereby tracking load appears to severely limit spatial memory capacity but memory load does not appear to interfere with position monitoring during tracking. This relationship suggests the possibility that spatial memory may support performance in position tracking and potentially also in traditional MOT.

56.4073 **Multiple object tracking is immune from a strong perceptual illusion** Harry Haladjian[1](haroutioun@gmail.com), Matteo Lisi[1], Patrick Cavanagh[1,2]; [1]Laboratoire Psychologie de la Perception, CNRS UMR 8242, Université Paris Descartes, [2]Psychological and Brain Sciences, Dartmouth College, Hanover, NH

The double-drift stimulus — a drifting gabor with orthogonal internal motion — produces a dramatic shift of its perceived location but no error in saccades that target it (Lisi & Cavanagh, 2015). In the current study, we used this stimulus within the context of a multiple object tracking task in order to test whether the attention involved in tracking is more like the form of attention used to execute saccades or like that which supports perception. Observers (n=7) were asked to track 1-4 targets among 4-7 distractors (with all trials containing 8 total identical moving objects); all targets and distractors were double-drift stimuli. If tracking engages a form of spatial attention that is related to saccades, we expect no effect on tracking performance compared to a control condition (where the gabors had no internal motion). Conversely, if tracking is based on a form of spatial attention that is independent of the saccade system we expect a loss of performance since targets and distractors would have large illusory shifts in location and direction. Results indicate an overall impairment for tracking objects with internal motion [$F(1,1882)=11.5$, $p< .01$], but pairwise comparisons for each level of tracking load show no significant differences between these conditions; tracking performance was essentially unaffected by the internal motion. This indicates that the tracking process can operate independently of the forms of attention that support perception, suggesting a dissociation between neural systems for perception and those for attention.

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56.4074 **Attentive motion tracking does not utilize eye-of-origin information** Amy Chow[1](ahychow@uwaterloo.ca), Deborah Giaschi[2], Benjamin Thompson[1]; [1]Department of Optometry and Vision Sciences, University of Waterloo, [2]Department of Ophthalmology and Visual Sciences, University of British Columbia

Previous reports suggest that eye-of-origin information contributes to performance on visual search and on 3D motion tasks. We investigated whether eye-of-origin information could be utilized by the attentional mechanisms involved in 2D multiple object tracking (MOT). We predicted that if attention could be directed towards information from one eye, performance of an MOT task would be better when the tracked objects were presented to one eye and the distractors to the other (dichoptic viewing) than when all objects were presented to both eyes (binocular viewing). The MOT stimulus consisted of 10 pseudo-randomly moving dots (1° diameter, 10°/s) presented within a 14 x 14° field. Participants tracked 4 dots for 5 seconds while fixating a central cross. Stimuli were viewed through frame sequential shutter-glasses. The target dots were cued for 2 seconds in a static presentation of the first stimulus frame prior to each trial. At the end of each trial a dot changed color and the participant indicated whether or not it was a target dot within a 2-AFC procedure. Sensory eye dominance was also estimated using a dichoptic global motion procedure. Participants with normal vision completed 60 trials for each of three conditions: 1) binocular viewing, 2) dichoptic viewing with target dots to the dominant eye and, 3) dichoptic viewing with target dots to the non-dominant eye. There were no significant differences in task accuracy between these three conditions (binocular viewing mean = 80% correct, SD 11%; dominant eye targets = 77%, SD 8%; non-dominant eye targets = 78%, SD 10%). These results imply that the attentional mechanisms involved in MOT do not utilize eye-of-origin information.

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56.4075 **Exploring the temporal dynamics of attentional reallocations with the multiple object tracking paradigm** Hauke Meyerhoff[1](h.meyerhoff@iwm-kmrc.de), Frank Papenmeier[2], Georg Jahn[3], Markus Huff[2]; [1]Leibniz-Institut für Wissensmedien, [2]Department of Psychology, University of Tübingen, [3]Institute for Multimedia and Interactive Systems, University of Lübeck

The dynamic environment of human observers requires continuous reallocations of visual attention in order to compensate for location changes of the attended objects. Particularly, situations with reduced spatial distance between targets and other objects in the display are crucial for keeping track of the target objects. In the present experiments, we explored how the temporal dynamics of such moments of reduced spacing affects the reallocation of visual attention. We asked participants to track four targets among indistinguishable distractors. Hereby, we manipulated whether target and distractor objects moved at a constant speed or whether their actual speed followed a sine wave profile. The variable speed oscillated around the constant speed thus maintaining average speed as well as travelled distance and average spatial proximity. The critical difference between the experimental conditions was that the durations of the events of spatial interference were more variable with variable speed profiles than with constant speed profiles. Particularly, the accelerations and decelerations of the variable speed profiles induced brief events of spatial interference at high object speeds as well as long events of spatial interference at slow object speeds. The overall duration of the events of interference, however, was indistinguishable between the conditions with variable and constant speed profiles. We observed inferior tracking performance with variable speed profiles relative to constant speed profiles (Experiments 1a and 1b). When we increased the number of pairs of targets and distractors moving with a variable speed profile (Experiment 2), performance declined continuously. Remarkably, tracking performance also declined when only distractors moved at variable speeds, suggesting that the dynamic changes in inter-object spacing rather than the variable speed impairs tracking (Experiment 3). In sum, our results provide evidence for a flexible allocation of the attentional resource toward targets suffering spatial interference by demonstrating the temporal constraints of the reallocation process.

56.4076 **Identity information of multiple moving objects is extracted in a serial manner during multiple identity tracking: An eye-tracking study** Lauri Oksama[1,2](loksama@utu.fi), Jie Li[3], Jukka Hyönä[4]; [1]National Defence University, [2]Academy of Finland, [3]Section of Applied Psychology, Beijing Sport University, [4]Department of Psychology, University of Turku

Some investigators argue that visual tracking is based on a parallel mechanism, others argue that tracking contains a serial component. In Experiment 1, we put previous theories into a direct test by registering observers' eye movements when they tracked identical moving targets or when they tracked distinct object identities. We found a qualitative difference between these tasks in terms of eye movements. When the participants tracked only position information, the observers had a clear preference for keeping their eyes fixed for a rather long time on the same screen position. In contrast, active eye behaviour was observed when the observers tracked the identities of moving objects. Experiment 2 investigated how observers extract identity information during multiple-identity tracking by adopting the gaze-contingent display technique. We manipulated in real time the presence/absence of the object identities while the participants tracked multiple moving objects. The results showed that when only the identity of the currently foveated object was presented, participants' tracking performance was as good as when the identities of all the objects were presented all the time. Moreover, when identity information was not available when the target was foveated, the performance dropped to the level observed in the condition where the object identities were presented only prior to object movement. The results yield strong support for the view that identity information of multiple moving objects is extracted in a serial manner during identity tracking, whereas the positions of identical moving targets can be tracked in parallel without the need of eye movements.

56.4077 **Using Color Combination to Predict Tracking Performance in Multiple Object Tracking** Chundi Wang[1](wangchundi@mail.bnu.edu.cn), Luming Hu[1], Xuemin Zhang[1,2,3]; [1]Beijing Key Lab of Applied Experimental Psychology, School of Psychology, Beijing Normal University, Beijing, China, [2]State Key Laboratory of Cognitive Neuroscience and Learning and IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing, China, [3]Center for Collaboration and Innovation in Brain and Learning Sciences, Beijing Normal University, Beijing, China

Surface features can be used during multiple object tracking. Previous studies found that some color combination conditions improved tracking performance, and some impaired tracking performance. However, there are mathematically 36100 color combination conditions for a tracking of four targets and four distractors colored in eight colors. Only a small proportion of combinations were covered in previous studies and how much of the impact of each combination for tracking has never been studied. The present study intended to construct a general linear model, by manipulating variables of different color combinations to predict the tracking performance. We decomposed three main predictive variables from the different color combinations of objects. First, the most important predictive variable was the color difference and similarity of target group and distractor group (STD). This predictive variable categorized different color combinations into three basic relations: inter-target grouping, distinct and target-distractor grouping (target-distractor paired). Second, the color variety complexity of target group (CT). Third, the color variety complexity of distractor group (CD). We assumed that STD and CT would affect the tracking performance, and CD would have little effect on tracking. Tracking performance would be better with the increase of color difference between the target group and the distractor group. However, the tracking performance would be worse with the color variety complexity of target group increase. We designed 20 different color combination conditions belonged to six major categories. Using multivariable linear regression (Enter), we found that the full model was statistically significant, and the prediction of tracking performance from STD and CT was statistically significant, however, it was not the case of CD. And, the interpretability of STD was much better than CT as expected. We conclude that the tracking performance can be well predicted from variables of color combinations of targets and distractors.

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56.4078 **Multiple Identity Tracking of Semantic-category Based Chinese Words: Visual-perceptual Processing or Semantic Processing** Jing Su[1], Xuemin Zhang[1,2,3], Liuqing Wei[1]; [1]School of Psychology, Beijing Normal University, [2]National Key Lab of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, [3]Center for Collaboration and Innovation in Brain and Learning Sciences, Beijing Normal University

Previous studies adopted simple physical features as objects' identities have revealed that visual distinctiveness or uniqueness of moving objects could enhance tracking performance in Multiple Identity Tracking task. The present study used two character Chinese words with semantic category information and visual distinctiveness as multiple identity tracking objects, and investigated which process played a more important role when both visual-perception and semantic category processing may occur simultaneously. Chinese words were selected from two categories represented land mammals and tools. The semantic category distinction of targets and distractors was manipulated in five conditions, the baseline condition: all tracking objects were one same word; the intra-category homogenous condition: targets and distractors were two different words from the same semantic category; the inter-category homogenous condition: the targets were one same word from one semantic category and the distractors were one same word from the other semantic category; the intra-category unique condition: tracking objects were eight different words from the same semantic category the inter-category unique condition: both targets and distractors were four different words from two different semantic categories. Results showed that tracking performance was significantly better than the baseline when targets and distractors had visual distinctiveness, and there was no difference between intra-category homogenous and inter-category homogenous conditions. Performances of unique conditions were both worse than that of the baseline condition, but the inter-category unique condition was better than the intra-category unique condition. These results indicated a resource-saving processing system that both visual and semantic category distinction could be utilized during multiple identity tracking of Chinese words. Visual perceptual processing played a more important role during tracking when there's no need for higher level cognitive processing. Semantic category distinction impaired tracking performance compared to the baseline condition, because the semantic category processing cost cognitive resources initially used for tracking.

Attention: Spatial selection and modulation 2

Tuesday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4079 **Covert attention within the foveola enhances fine discrimination** Martina Poletti[1](martinap@bu.edu), Marisa Carrasco[2], Michele Rucci[1]; [1]Department of Psychological and Brain Sciences, Boston University, [2]Department of Psychology and Center for Neural Science, New York University

Background: Vision is not homogenous within the foveola, the high-acuity region of the fovea. Tiny saccades are finely controlled to compensate for this inhomogeneity by bringing the locus of highest visual acuity in the foveola on the object of interest (Poletti et al, 2013 Current Biology). We recently showed that such high level control is not limited to oculomotor activity, but it also extends to covert attention. Attention can be selectively allocated toward objects separated by only 20 arcminutes in the foveola, leading to faster detection of targets presented at the attended location. Here, we investigated whether microscopic shifts of covert attention can also improve sensitivity (d') in a visual discrimination task. Methods: Observers (n=5) reported the orientation of a tiny bar (7x2 arcminutes) that could appear at four different locations at 14 arcminutes from the center of gaze. The target was preceded by a cue that in most trials provided information about its future location. Measuring shifts of attention within the foveola is extremely challenging because fixational eye movements displace the retinal stimulus by an area as large as the foveola itself. We circumvented this problem by using a custom apparatus to stabilize the stimulus on the retina. Results: Performance was higher when the cue was informative about the target's location (valid trials: d'=2.2±0.3) than when it was not informative (neutral trials: d'=1.8±0.4) or provided wrong information (invalid trials: d'=1±0.5). There was no speed-accuracy trade-off: observers responded faster in the valid trials. Conclusion: Covert attention enhances visual discrimination not only at parafoveal and peripheral locations, but also within the foveola. These findings reveal that the resolution of attention is much finer than thus far assumed. This mechanism may enable serial processing or privileged parallel processing of crowded foveal stimuli during fixation.

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56.4080 **Eye abduction reduces competition in the oculomotor system** Paul Boon[1](p.j.boon@vu.nl), Jan Theeuwes[1], Artem Belopolsky[1]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam

It is well established that there is a tight coupling between covert attention and the eye movement system. It is not yet clear whether there is a functional relationship between the two systems. Recent studies using the Posner cueing paradigm have demonstrated that preventing participants from executing a saccade reduces the attentional benefits associated with allocation of covert attention. One such technique involves abducting the eye in the orbit and presenting the stimuli outside of the effective oculomotor range (Craighero et al., 2004). In the present study we used saccadic curvature to examine whether eye abduction also reduces the competition in the oculomotor system. Saccadic curvature arises from competition within the oculomotor map when a visual distractor competes with the target. Typically, this causes saccades to curve away from the distractor. We experimentally reduced the ability to execute saccades by abducting the eye 30° into the temporal hemifield (monocular vision). This way the peripheral part of the temporal hemifield was located outside of the oculomotor range. Participants made a vertical eye movement while on some trials a distractor was shown either at a close or remote location in one of the hemifields. The results showed a decrease in curvature away from distractors located outside the oculomotor range. However, no such decrease was observed in the nasal hemifield, where saccade planning was unaffected. The results demonstrate that the inability to plan a saccade results in a decrease of distractor evoked activity in the oculomotor system even when the retinal stimulation is kept the same. The results are consistent with the premotor theory, which proposes that attention has emerged as an unavoidable consequence of movement planning.

56.4081 **Localization of flash grab targets is improved with sustained spatial attention** Nika Adamian[1](nika.adamian@parisdescartes.fr), Patrick Cavanagh[1,2]; [1]Université Paris Descartes, [2]Psychological and Brain Sciences, Dartmouth College, Hanover, NH

We examined the effect of spatial and temporal predictability on the flash grab illusion (Cavanagh & Anstis, 2013) where a target is briefly flashed on top of a moving texture as it reverses direction and its position is seen displaced in the direction of motion following the reversal. On each trial, subjects were shown a large rotating textured disc. At some point during the trial the motion reversed direction and at the same time a small probe was flashed on top of the texture and subjects reported its location. In the first experiment we varied spatial and temporal certainty together. The probe was presented at the same location on multiple consecutive reversals. We found that upon the first presentation at an unexpected location and time, the probe was perceived significantly more shifted compared to the subsequent repeat presentations. In the second study we compared the effects of spatial and temporal predictability on the strength of the

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flash grab illusion. Trials were presented in blocks and before each spatial block a cue indicated a range of possible target locations, whereas before each temporal block, a range of possible timings of the reversal was given. We found that the flash grab effect was reduced if the spatial distribution of targets within a block was limited to a range of 90° or less. By contrast, increasing the temporal predictability of the target did not reduce the flash grab effect. We assume that with an uncertain location, attention would be delayed in arriving at the test, increasing the motion-induced position illusion (Müsseler & Ascherschleben, 1998). However, temporal uncertainty does not appear to affect this attentional delay.

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56.4082 **Attention and Metacontrast Masking do not Interact** Sevda Agaoglu[1,3](sagaoglu@uh.edu), Bruno Breitmeyer[2,3], Haluk Ogmen[1,3]; [1]Department of Electrical and Computer Engineering, University of Houston, [2]Department of Psychology, University of Houston, [3]Center for Neuro-Engineering and Cognitive Science, University of Houston

The visual system is flooded with sensory information. Only a subset of this information is selected and stored temporarily for further processing. Visual masking and spatial attention are two of the processes that control the information transfer from sensory memory to short-term memory. A natural question is whether these processes interact or operate independently. Earlier studies suggested that metacontrast masking and common-onset masking interact with attention. However, recent studies reported no interactions between attention and common-onset masking, and pointed out that the earlier studies suffered from ceiling and/or floor artifacts. Our analysis of previous studies reporting metacontrast-attention interactions revealed similar problems. Hence, we investigated metacontrast-attention interactions by using an experimental design in which ceiling/floor effects are avoided. Observers fixated at the center of the display and reported the orientation of a target bar. We manipulated attention by set-size; i.e., the number of oriented bars, presented around a virtual circle, was either two or six. The target bar was indicated by a surrounding ring (metacontrast masking) or a small neighboring cue (baseline). We adjusted target-mask luminances for each observer separately to avoid ceiling (performance in the baseline) and floor (chance level) effects. The stimulus onset asynchrony between the target and the mask (or the cue) was varied to fully capture the classical U-shaped masking functions. Response errors were computed as the difference between the actual and reported orientations. We investigated masking-attention relations by analyzing two different aspects of performance: (i) The mean absolute response-errors, and (ii) the statistical distribution of signed response-errors. Our results show that attention and masking modulate observers' responses without interacting with each other, suggesting that they are independent processes. Statistical modeling of the distribution of signed response-errors also suggests that attention and masking exert their effects by independently modulating the probability of "guessing" behavior.

56.4083 **Does similarity affect the order in which items are scrutinized in visual search? No.** Alejandro Lleras[1](Alejandro.Lleras@gmail.com), Trisha Patel[1], Simona Buetti[1]; [1]University of Illinois

A common assumption in several visual search theories is that the similarity between items in the display and the target template should impact or even determine the order in which those items are scrutinized during visual search. Here, we tested that assumption and failed to find support for it. We selected two different types of "candidate" stimuli (i.e., distractors that are sufficiently similar to the target as to require attentive scrutiny): (i) rotated Ls and (ii) rotated Ls with one of the two lines shifted inward so as to create a T-junction between the two lines. The target was a rotated T, thus the rotated L stimuli were less similar to the template than the t-joined L stimuli. The similarity relationship was verified by measuring the search slopes for displays only containing one of the two types of L distractors, and by a multi-dimensional scaling analysis. Furthermore, we varied whether or not the display contained lure stimuli (i.e., distractors that are sufficiently dissimilar to the target as not to require attentive scrutiny). Supporting previous findings from our lab, participants successfully "screened out" the lures, and the cost to do so was unaffected by the type of L-distractors in the display. Thus, participants can guide focused spatial attention towards candidate stimuli. However, the results also indicated that participants did not guide attention preferentially towards more similar candidate stimuli (shifted Ls) than the less similar ones (rotated Ls). These findings are consistent with our proposal that target-distractor similarity does not play a role in the ranking of to-be-scrutinized distractors in a scene (Buetti et al, submitted). The results also indicate that once peripheral stimuli are sufficiently similar to the target, search slopes reflect template-comparison processes, rather than differences in attentional guidance.

56.4084 **Accurate location information modulates perceptual distraction during search** Dipanjana Das[1](ddas4425@gmail.com), Søren Kyllingsbæk[2], Claus Bundesen[2], Barry Giesbrecht[1]; [1]Psychological & Brain Sciences, University of California, Santa Barbara, [2]Center for Visual Cognition, University of Copenhagen

Accurate information about the spatial location of objects during visual search influences the allocation of processing capacity to task-relevant and task-irrelevant information. According to Load theory (Lavie, 1995), processing capacity is allocated to stimuli presented at task-relevant locations and any remaining capacity spills-over to stimuli at task-irrelevant locations. This scheme implicitly assumes that stimulus location information is accurate and available before the allocation of processing capacity. However, performance in these tasks is explained by an instantiation of the Theory of Visual Attention (TVA, Bundesen, 1990) that assumes parallel computation of location information and stimulus identity (Kyllingsbæk et al., 2014; Kyllingsbæk, 2015). If true, then manipulations that improve the accuracy of the spatial information about the locations of task-relevant and task-irrelevant stimuli should serve to reduce the extent to which irrelevant information interferes with performance. We tested this prediction using an unspeeded hybrid flanker-visual search task (Lavie & Cox, 1997; Kyllingsbæk et al., 2014) in which information about stimulus locations was provided using placeholders. Over the course of 6 sessions (3456 trials), participants (n=6) reported whether the search target was an X or Z while ignoring congruent/incongruent stimuli at the flanker locations presented outside the search display. Consistent with the prediction, there was no effect of flanker congruency on target discrimination ($F(1,5)=.897$, $p=.387$). A direct comparison to the results of an identical task conducted without placeholders (Kyllinsbæk et al., 2014) revealed a significant interaction ($F(1,10)=5.945$, $p=.035$), such that when placeholders were present, the flankers did not interfere with performance, but when placeholders were absent, flanker interference was observed. These findings are consistent with the notion that information about stimulus location and identity are processed in parallel and together influence the efficient allocation of perceptual processing capacity.

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56.4085 **Electrophysiological correlates in healthy individuals of galvanic vestibular stimulation protocols used to treat hemi-spatial neglect** Rachael Morris[1](rm499@kent.ac.uk), Catriona Scrivener[2], Joseph Brooks[1]; [1]School of Psychology, University of Kent, [2]School of Systems Engineering, University of Reading

Galvanic Vestibular Stimulation (GVS) is a non-invasive form of neural stimulation which involves applying weak, electric current over the mastoid processes. The therapeutic potential of GVS has been documented in a number of recent studies. Perhaps most notably, studies have shown that even brief periods of stimulation are able to provide transient relief from symptoms of the attentional disorder hemi-spatial neglect. Despite this, the underlying mechanisms associated with recovery remain largely unknown. The current study therefore investigated the effect of GVS on the ERP component N2pc, thought to be associated with target detection among distractors. As a preliminary study, neurologically healthy participants were used as a more homogeneous sample. EEG was recorded from 14 participants whilst completing a change detection task. Testing took place over two separate days. During one session, sub-sensory GVS (< .5mA) was administered, while a sham stimulation was administered during the other. N2pc amplitude was compared for active versus sham stimulation, as well as comparing hit and missed targets. Relative to a sham condition, N2pc amplitude for missed targets was significantly increased during active GVS. Additionally, while N2pc amplitude in the sham condition was significantly different for hit and missed targets, this difference was removed when participants received active GVS. This may suggest that GVS increases the ERP amplitude for missed targets so that they more closely approach a sensory threshold at which conscious, visual awareness is possible. Interestingly, while a clear directional focus of attention was demonstrated during sham stimulation, indicated by a significant N2pc and reverse N2pc for detected and missed targets respectively, this was removed during active GVS. Our results may therefore provide the first tentative evidence that low levels of Galvanic Vestibular Stimulation applied to the healthy brain can suppress underlying mechanisms usually associated with directional focus of attention.

56.4086 Age-related changes in the hemispheric lateralisation of pre-stimulus alpha. Gemma Learmonth[1, 2](g.learmonth.1@research.gla.ac.uk), Monika Harvey[2]; [1]Centre for Cognitive Neuroimaging, School of Psychology, University of Glasgow, Glasgow, Scotland., [2]School of Psychology, University of Glasgow, Glasgow, Scotland.

The covert direction of attention towards one side of space is typically accompanied by a reduction of inhibitory alpha band (8-13Hz) activity within the contralateral visual cortex (Rihs et al., 2007; 2009; Thut et al., 2006). Indeed, larger alpha modulations are correlated with improved accuracy and reaction times during cued detection/discrimination tasks (Thut et al., 2006). Although older adults show a preserved ability to direct their endogenous attention, the dynamic neural modulation of contralateral alpha observed in young adults is diminished in this group (Hong et al., 2015). Here we aimed to investigate whether pre-stimulus alpha asymmetry between the left vs right visual cortex is present in an uncued spatial attention paradigm, and secondly whether this pattern of hemispheric lateralisation changes as a consequence of healthy aging. We presented 20 young (age 18-25) and 20 older (age 60-80) adults with a lateralised visual detection task during EEG recording. Temporal spectral evolution (TSE) was used to quantify alpha amplitude in the left (P3/P7/O1) vs right (P4/P8/O2) posterior regions of interest (ROI) within a 1000ms pre-stimulus window. Overall, young adults exhibited a larger pre-stimulus alpha amplitude compared to older adults. There was an interaction between age and ROI, with young adults displaying a larger alpha asymmetry towards the right vs left ROI and, conversely, older adults in the left vs right ROI. We are currently working towards analysing this data on a single trial basis to investigate whether these age-related differences are predictive of our behavioural measures. We conclude that there are specific changes in the hemispheric lateralisation of alpha band activity during the healthy aging process, and that these changes are observable in tasks which do not require an endogenous allocation of attention.

56.4087 When does visual attention need to be retargeted? A study of the neural correlates of attentional deployment to two sequential targets Brad Wyble[1](bwyble@gmail.com), Chloe Callahan-Flintoft[1]; [1]Department of Psychology, Penn State University

The deployment of visual attention is associated with the N2pc EEG component, although it is not entirely clear what mechanism this component reflects. A computational model by Tan & Wyble (2015) suggests that this component reflects the transient process of engaging attention at the location of a stimulus in preparation for consolidating that information into memory (i.e. locking-on to a target's location). This conclusion stems from previous findings that the N2pc is only triggered by the first of two sequential targets at the same location, but is triggered by both targets when presented at different locations. We tested predictions from the Tan-Wyble model. First, we replicated the crucial finding that the N2pc is missing for a second target. Next, we tested a prediction that if there are distinct attention maps for different kinds of targets then there should be two N2pcs for sequential targets of different types. Two RSVP streams presented distractors (black letters) and two targets of different types (black digits and red letters) bilaterally. Presumably, separate attentional maps would each deploy attention to their respective target types, resulting in two N2pcs. However the results indicated only a single N2pc, which suggests a single attentional map. Next, we varied the latency between two targets to determine the point at which attention needed to be re-engaged following successful deployment. The second N2pc was clearly present for targets separated by 450ms but not 150ms, even on trials in which subjects reported both targets. This suggests that attention to a location needs to be re-engaged after several hundred milliseconds even though subjects know with certainty the target will be there. Finally, we extended the finding of a missing N2pc to three consecutive targets, suggesting that attentional engagement states can persist across a string of task-relevant items at a particular location.

Acknowledgement: National Science Foundation 1331703

56.4088 Two modes for seeing relations between objects Audrey Michal[1](audrey.lustig.michal@northwestern.edu), Stacey Parrot[1], Steven Franconeri[1]; [1]Northwestern University

Past work has revealed two distinct types of spatial relation representations: categorical (e.g., 'X left of Y') and coordinate (e.g., 'X is 1 cm away from Y'; Kosslyn et al., 1989). Does a similar dissociation exist for relations based on features other than spatial location, such as size? By measuring eye movements, we show that people adopt distinct attentional modes when representing different types of magnitude relations in the same display (two bars). In Experiment 1, when asked to judge a directional relation ('Are the bars arranged short-tall or tall-short?'), participants systematically isolated one bar with their attention. In contrast, when asked to judge a nondirectional relation ('Are the bars the same or different heights?'), participants systematically shifted their gaze toward the right. A rightward shift would place the stimuli in the left visual field, allowing the bars to be processed more holistically by the right hemisphere. In a second experiment, we encouraged one group of participants (holistic group) to extract relations by imagining a line connecting the tops of the two bars (directional: 'Is the line sloped positively or negatively?'; nondirectional: 'Is the line flat or sloped?'). As a control, we included an individuated group of participants who used the same perceptual framing as Experiment 1. The holistic framing changed participants' eye movements such that directional relations were extracted more similarly to nondirectional relations than directional relations in the individuated group. Together, these results reveal two distinct modes for extracting magnitude relations (locally versus holistically), and that these modes map onto how categorical and coordinate spatial relations are processed, respectively. They also show that people can be induced to extract relations locally or holistically for the same display, either by manipulating the type of judgment (directional/nondirectional) or the perceptual framing (individuated/holistic).

Acknowledgement: NSF SLC Grant SBE-1041707

56.4089 Attention field models capture biases in perceived position Barrie Klein[1](b.p.klein@uu.nl), Chris Paffen[1], Susan te Pas[1], Serge Dumoulin[1]; [1]Department of Experimental Psychology, Utrecht University

Attention is the mechanism through which we are able to select relevant information from our visual environment. Attention field models describe the effects of attention on neural processing and predict that receptive fields are attracted towards the attended location. We have recently demonstrated this attraction using fMRI and found that the amount of attraction varies across the visual hierarchy (Klein et al, Neuron, 2014). Here, we apply an attention field model to human perception: we predict that receptive field attraction results in a bias in perceived position, which depends on the size of the underlying receptive fields. Participants were presented with two pairs of Gabors and judged which of the two pairs was spaced closest together. Attention was directed to one of the pairs using exogenous cues. In two experiments we varied (1) the eccentric position and (2) the spatial frequency of the Gabors. As receptive field size increases with increasing eccentricity and decreasing spatial frequency, we expect a larger bias in the perceived position for higher eccentricities on the hand and lower spatial frequencies on the other. Our results show that the positional bias increased with eccentricity, but did not vary with spatial frequency. We also found that the increase of the positional bias with eccentricity closely matches the predictions derived from an attention field model. We conducted control experiments to exclude possible alternative explanations and to control for confounds. In conclusion, attention field models can account for some positional biases, but do not account for the spatial frequency manipulation. We speculate that the attention field as elicited by our cues operates in visual space but not in the frequency domain. Our results suggest that attention field models provide a useful framework to understand effects of attention on human perception.

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56.4090 Attention correlates with saccade amplitude modulations caused by gaze-contingent filtering of the visual field Jochen Laubrock[1](laubrock@uni-potsdam.de), Anke Cajar[1], Ralf Engbert[1]; [1]Department of Psychology, University of Potsdam, Germany

Degrading real-world scenes in the central or the peripheral visual field yields a characteristic pattern: mean saccade amplitudes increase with central and decrease with peripheral degradation. Does this effect reflect a mere adaptation of the saccadic system to the changed visual conditions or modulations of selective attention? If saccade amplitudes reflect attentional modulation, the observed pattern predicts more focused attention in the central region with peripheral degradation and an attentional bias toward the periphery with central degradation. To investigate whether the amplitude pattern reflects attention, we measured the detectability of peripheral (Experiment 1) or central targets (Experiment 2) during scene viewing when low or high spatial frequencies were gaze-contingently filtered in the central or the peripheral visual field. Target detectability was matched between full-field filter condition by use of an adaptive threshold technique. Relative to an unfiltered control condition, peripheral filtering induced a decrease of the detection probability for peripheral, but not for central targets (tunnel vision). Central filtering decreased the detectability of central, but not of peripheral targets. Additional post-hoc analyses comparing polar distributions of target detection probability as a function of target-saccade angle and filtered region are compatible with

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the interpretation that saccade amplitudes and direction are computed in partial independence. In conclusion, the present experimental results strongly indicate that saccade amplitudes reflect attentional modulations.

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56.4091 The eyes don't have it after all? Attention is not biased towards faces or eyes Effie Pereira[1](effie.pereira@mail.mcgill.ca), Elina Birmingham[2], Jelena Ristic[1]; [1]Department of Psychology, McGill University, [2]Faculty of Education, Simon Fraser University

Social cues like faces and eyes are thought to exert powerful effects on attention. Numerous studies have demonstrated that faces and eyes preferentially attract eye movements in both simple and complex contexts – greater number of fixations are directed towards faces and eyes when participants are presented with faces in isolation, scenes portraying social content, and during free viewing of dynamic social interactions. However, it remains unclear if this oculomotor preference reflects preferential attentional selection, as no studies to date have distinguished between eye movements and attention with respect to face or eye selection. Here, we investigated if attention preferentially selects faces and eyes by using a modified dot-probe task. Participants were presented with displays depicting photographs of a face and a house, which were equated for size, distance, and low-level properties. Each stimulus could be positioned on the left or right of fixation and presented in either upright or inverted orientation. After 250ms, the cues offset and a target probe demanding a discrimination response was presented at the previous location of the face (eyes or mouth) or at the previous location of the house (top or bottom). Each combination of the cue and target was equiprobable. When participants were asked to perform the task covertly by maintaining central fixation, no attentional bias was observed for either the face or the eyes relative to the house. When eye movements were not restricted, similar findings emerged, indicating no attentional bias for either the face or the eyes across both manual and oculomotor measures. The only reliable result was an increased proportion of oculomotor breakaways towards the eyes during the cue period; however, the magnitude of this effect did not predict the magnitude of attentional selection. Together, these findings challenge the prevalent notion that faces and eyes preferentially and spontaneously capture human attention.

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56.4092 Hand proximity biases overt – not covert – orienting Eric Taylor[1](j.eric.t.taylor@gmail.com), Minal Patel[1], Jay Pratt[1]; [1]University of Toronto

The various effects of altered vision near the hands are sometimes hard to reconcile. For example, the first two major investigations in this literature reported near-hand attentional prioritization and no interaction with peripheral cues (Reed, Grubb, & Steele, 2006) and prolonged attentional disengagement and interactions with peripheral cues (Abrams, Davoli, Du, Knapp, & Paull, 2008). Noting these and other discrepancies, the modulated visual pathways (MVP) theory proposed an alternate account, whereby hand proximity up-regulates magnocellular processing via the dorsal stream. This theory posits an alternative explanation for earlier reports of attentional prioritization (faster detection RTs) for peripheral targets in near-hand space: Eye movements should be faster toward stimuli appearing in near-hand space due to an enhanced collicular response. We conducted two experiments to investigate this alternative account. First, we conducted a close replication of Reed et al.'s (2006) spatial cueing task using eye-tracking and a strict gaze-contingent window at fixation, forcing covert rather than overt orienting. When eye movements were expressly forbidden, we failed to replicate the faster detection for stimuli in near-hand space, suggesting that earlier reports were caused by biases in eye movements or starting eye position. Second, we put MVP to the test in a fixation-offset gap effect paradigm. Participants made speeded eye movements to peripheral onsets either with or without a fixation stimulus. The presence of a fixation stimulus inhibits the activity of burst neurons in the superior colliculus, slowing eye movements. According to MVP, hand proximity should up-regulate the collicular signal, reducing saccadic RTs in the presence of a fixation stimulus. Consistent with this expectation, we observed faster saccadic RTs with a fixation stimulus near versus far from the hand. This reduced gap effect is difficult to explain with an attentional account of altered vision near the hands.

56.4093 Dissociating inhibitory mechanisms with actions and objects Matthew Hilchey[1, 2](matt.hilchey@dal.ca), John Christie[1], Jay Pratt[2]; [1]Department of Psychology and Neuroscience, Dalhousie University, [2]Department of Psychology, University of Toronto

Our hypothesis is that that the inhibition found a few hundred milliseconds following the presentation of a peripheral cue can be dissociated into two completely separate mechanisms. One mechanism biases action against the direction of previously programmed saccades (action-based inhibition) whereas the other biases perception against covertly processed visual inputs (attention-based inhibition). This study manipulates hand position (action) and placeholder presence (objects) to demonstrate this dissociation. In Experiment 1, we mapped the time course of covert peripheral cueing with and without placeholder objects while instantiating strict eye movement controls and requiring manual responses to visual stimuli. Crucially, inhibition was obtained only when placeholder objects were present. In a second experiment, where participants made eye movements to the cues and then returned to fixation, we found inhibition when placeholders were present or absent. Experiment 3 further distinguished between these forms of inhibition by manipulating hand position. Across four separate blocks, we manipulated whether the participants' hands were near or far from the visual display and whether they made an eye movement or not to the cue. With eye movements to the cues, inhibition was amplified in near- relative to far- hand space. When gaze was held at fixation, inhibition was attenuated in near- relative to far- hand space. Collectively, the findings suggest that action-based inhibition is amplified by hand proximity and is encoded in space-based coordinates whereas attention-based inhibition is attenuated by hand proximity and is encoded principally in object-based coordinates.

56.4094 Action video games improve math abilities in children with developmental dyscalculia Sandro Franceschini[1,2](sandrofranceschini@gmail.com), Simone Gori[2,3], Monja Tait[4], Elisa Casagrande[5], Carlo Robino[6], Claudio De'Sperati[6], Andrea Facoetti[1,2]; [1]Department of General Psychology, University of Padua, Padova, Italy, [2]Child Psychopathology Unit, Scientific Institute "E. Medea", Bosisio Parini, Lecco, Italy, [3]Department of Human and Social Sciences, University of Bergamo, Bergamo, Italy, [4]Developmental Neuropsychology Academy, Parma, Italy, [5]Department of Psychology, University of Urbino, Urbino, Italy, [6]Laboratory of Action Perception and Cognition, "Vita-Salute San Raffaele" University, Milan, Italy

Developmental dyscalculia (DD) is a neurodevelopmental disorder of biological origin. DD is a specific learning disability that affect the development of numerical and arithmetic functioning with estimated prevalence rates between 3 and 6%. The basic number system seems to be evolutionary, but numerical and arithmetic skills are also influenced by cultural factors, especially the preschool and school experience. Children with DD have problems in mastery many mathematical abilities like counting, magnitude processing, arithmetic and spatial number representation. Several neurocognitive functions are considered at the basis of DD, such as visuo-spatial, attentional skills and executive functions. Starting from the evidence that these abilities can be improved by intensive use of specific video games, we tested the possibilities to improve mathematical skills with an action video game training. We tested numerical cognition and visuo-spatial attentional skills as well as overt visual exploration in two matched groups of children with DD before and after they played action or non-action video game for nine sessions of 80 min per day (12hrs). We found that only the group trained with action video game improved in number sense and arithmetic skills. Also visuo-spatial attentional skills improved after action video game training, without however translating into any evident modification of oculomotor exploratory activity. Our results show that a fun training of visual and attentional processing impacts on mathematical skills, unveiling the causal role of visuo-spatial attention in numerical cognition. Action video game could provide an efficient remediation of DD. Considering that visuo-spatial attention can be proficiently trained in infants using specific video games, early and inexpensive prevention programs could be developed to reduce the incidence of DD.

56.4095 Number subliminally primes area judgments: Novel evidence for a general magnitude system in human adults Stella Lourenco[1](slouren@emory.edu), Vladislav Ayzenberg[1]; [1]Department of Psychology, Emory University

Although researchers agree that number and other magnitudes are represented in analog format, there is disagreement about whether these representations form part of an integrated system, the so-called 'general magnitude system' (Walsh, 2003). Here we used a subliminal priming paradigm to test for interactions between different magnitudes (number and area) when one magnitude (number) was not consciously detectable. On each trial, participants were presented with a pair of black and white Arabic digits as subliminal primes (e.g., white 4 and black 8). Each digit pair was presented for a short duration (43 ms) and sandwiched between two masks, preventing conscious detection. Participants were then presented with target displays of black and white two-dimensional shapes (lasting 200 ms), and tasked with judging which array was larger in cumulative surface area (Experiment 1). We found significant congruity effects. That is, participants were both more accurate and faster on trials in which the mapping between color and relative number for the Arabic digits matched the mapping between color and relative surface area in the non-symbolic arrays (e.g., a prime display with a white 4 and a black 8 followed by a target display with smaller white surface area and larger black surface area) than when there was a mismatch (white 4 and black 8 followed by large white area and small black area; ps < .01). These findings suggest direct connections, or overlap, between representations of number and area, and because the primes were subliminal, mediation by common verbal labels was not a viable alternative explanation. Moreover, in a subsequent experiment (Experiment 2), we ruled out an alternative account that would explain congruity in terms of post-representational (i.e., decision) effects. Taken together, these experiments provide unique support for a general magnitude system that integrates numerical and non-numerical magnitudes

Visual Search: Attention

Tuesday, May 17, 2:45 - 6:45 pm
Poster Session, Pavilion

56.4096 Investigating Linear Separability in Visual Search for Orientation

Garry Kong[1](garry.kong@sydney.edu.au), David Alais[1], Erik Van der Burg[1,2]; [1]School of Psychology, University of Sydney, [2]Department of Cognitive Psychology, Vrije Universiteit Amsterdam

Visual search for orientation is often thought of in terms of the angular difference between the target and distractors and modelling typically use four reference orientations: 0°, 45°, 90° and 135°. However orientation is a dimension which wraps around after 180° and studies on orientation in visual search often run into problems with linear separability, a phenomenon in visual search where the presence of distractors that flank the target along a given dimension makes search for that target difficult. We investigated the limits of linear separability in orientation by systematically varying both the target orientation (0°, 15°, 45°, 75° and 90° from vertical) and the angular difference between target and distractors (7.5° to 75°). Displays were presented for one second and we measured participants' accuracy at detecting the presence of a gap on the target. Psychometric curves were fitted to the accuracy data, which showed the lowest thresholds for 0 and 90° targets, followed by 45°. The highest thresholds were found for 15° and 75°. However, the lapse rate for 45° targets was much greater than for the other target orientations. We suspect that participants are creating an on-line representation of 45° using their internal representations of vertical and horizontal, allowing for a higher threshold than 15° and 75°, which do not have accessible representations. However, the on-line nature of this representation results in slower processing times, leading to a higher lapse rate. Search for the 15° and 75° targets are likely treated as search for a slightly off 0° and 90° target respectively, leading to greatly increased thresholds.

56.4097 Pop-out in feature search is spatiotopic.

Cécile Eymond[1](cecile.eymond@gmail.com), Patrick Cavanagh[1,2], Thérèse Collins[1]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes, CNRS, [2]Psychological and Brain Sciences, Dartmouth College, Hanover, NH

In this study, we investigated whether the attentional focus of a feature search is processed in a spatiotopic or retinotopic reference frame. A search array with a color singleton was presented just before and after a saccade. The pre-saccadic array was presented 50 ms after the saccade cue providing approximately 150 ms viewing time prior to the saccade. The array was again present after the eye movement for an additional 40 to 50 ms. White markers were added to all items in the post-saccadic array and participants reported the position of the marker (top or bottom) on the target item. Following the saccade, the search target (color singleton) was either at the same location as before (spatiotopic condition), or exchanged places with a distractor so that the target occupied the same retinal location as before (retinotopic condition). Distractors remained at their spatiotopic locations (except for the one that traded places with the target). A control condition was identical in every way except that there was no pre-saccadic array presentation allowing us to determine if any information was accumulated during the pre-saccadic preview, and if so whether it was in retinotopic or spatiotopic coordinates. Results showed a reaction time advantage when the search array was presented both before and after the saccade when the search target was at the same spatiotopic location across the saccade, but not when it was at the same retinotopic location. This suggests that the capture of attention by a pop-out target is remapped across eye movements and is available immediately on saccade landing at the same spatial location the target had prior to the saccade.

Acknowledgement: This research was supported by the ERC Position (P.C.)

56.4098 Individual Difference in Spatial Updating Revealed in Location Probability Cuing

Ying Fang[1](fy090801@163.com), Shiyi Li[1,2], Nadia Wong[2], Xuejun Bai[1], Hong-Jin Sun[2]; [1]Academy of Psychology and Behaviour, Tianjin Normal University, [2]Department of Psychology, Neuroscience & Behaviour, McMaster University

In a visual search task, if target appears more frequently in one region of the scene, over time, participants will implicitly learn the target location probability. Jiang & Swallow (2012), using letter search task, demonstrated that the attended locations are viewer centered and are not updated with viewer movement. In this study, we reexamined this issue using computer rendered illustrations of 3D scenes with clear orientation information. During learning, across multiple trials, the target was more often found in one, rich quadrant than in any one of sparse quadrants. In the testing phase, the target appeared in each quadrant with the same probability. Participants learned the probability from one view (Experiment 1) or two views 180° apart (but with the location of the rich quadrant fixed relative to the environment, Experiment 2) and, before testing, moved to a view 90° from the initial learning viewpoint. Results of both experiments demonstrated probability cuing in the training phase. In the testing phase, lack of updating (lowest reaction times found in the quadrant that maintained the same spatial relationship with the viewer as the previously rich quadrant in the learning phase) were found for most participants in Experiment 1 but only two third of the participants in Experiment 2, while the results for the rest of the participants suggest updating. Moreover, the updating tendency did not relate to the ability in identifying the rich quadrant after the search task. While the results of Experiment 1 demonstrated the tendency of lack of updating by most participants, when fixed spatial relations between the stimuli and viewer or between stimuli and environment are both possible, the results of Experiment 2 suggest that when participants were given feedback on the stable relation between the stimuli and environment, some participants have the capacity to update as they move.

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56.4099 Binocularity and Visual Search – Revisited

Bochao Zou[1,3](bzou@bwh.harvard.edu), Igor Utochkin[2], Yue Liu[1], Jeremy Wolfe[3]; [1]School of Optoelectronics, Beijing Institute of Technology, China, [2]Laboratory for Cognitive Research, National Research University Higher School of Economics, Russia, [3]Visual Attention Lab, Harvard Medical School and Brigham & Women's Hospital, United States

How does dichoptic information guide attention in visual search? Wolfe and Franzel (1988) reported that binocular rivalry could guide attention only weakly but that binocular luster (shininess) "popped out", producing very shallow RT x set size functions. We have revisited the topic with new and improved stimuli and found that our lustrous stimuli did not always pop-out while search for rivalry can be quite efficient. Stimuli were presented on an imaginary circle. In Experiment 1, ~1.5 deg. gratings were presented to each eye: Orthogonally oriented to produce rivalry, same orientations to produce fusion. Search for rivalrous targets was more efficient than search for fused targets but still inefficient (RT x setsize slopes: 29 vs. 58 msec/item). In Experiment 2, each stimulus was a 2x2 checkerboard of vertical and horizontal gratings so every stimulus contained both orientations. Now search for rivalrous pairs was much more efficient (12 msec/item). The use of checkerboard stimuli may eliminate distracting orientation salience signals that masked the salience of rivalry in Experiment 1. In Experiment 3, 9 observers searched for shiny disks defined by binocular luster among matte disks with variable grey levels (eliminating reliable contrast and luminance cues). Luster is produced by presenting darker disks to one eye; lighter to the other. Search for targets defined by luster among matte distractors is fairly efficient (Target Present: 16 msec/item, average error rate 2.8%). In Experiment 4, observers searched for two types of targets (white shiny or black shiny) among two types of distractors (white matte or black matte) or vice versa. Search for lustrous targets among matte distractors was markedly more efficient than search for matte among luster (Target Present: 15 ms/item vs. 47 ms/item, average error rate 7% vs. 21%). This clear asymmetry suggests that luster may serve as a basic feature in visual search.

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Tuesday PM

See page 3 for Abstract Numbering System

56.4100 **Precise Guided Search** Matthew Cain[1,2](matthew.s.cain6.civ@mail.mil), Jeremy Wolfe[2,3]; [1]U.S. Army Natick Soldier RD&E Center, [2]Brigham & Women's Hosptial, [3]Harvard Medical School

Models of visual search usually content themselves with predicting average results (e.g., the mean and, perhaps, distribution of response times). If they are precise in predictions about single trials, it is under very reduced conditions (e.g., few items, only one or two of which are salient). Using a hybrid foraging search paradigm, we have attempted to predict the specific targets that will be selected in a complex display, over the course of many seconds. In hybrid foraging, observers search for multiple instances of several types of target. 22 participants performed three search tasks, always foraging for two target types: Feature search (e.g., blue and green squares among yellow and red squares), Conjunction search (e.g., green circles and blue squares among green squares and blue circles), and Spatial Configuration search (e.g., "p" and "d" among "b" and "q"). Each display held 80–140 moving items, 20–30% of these were target items. Observers were instructed to maximize the rate at which they clicked on targets. Targets disappeared when clicked and observers could switch to new displays at any time. A version of Guided Search was developed that could predict the identity and location of the next item to be selected. It had two basic rules: If there was another target of the type just collected within 400 pixels, the closest of those was selected; if not, the closest target of another type was selected. With these, we could predict the specific next item found for 60% of target collections in the Feature search, 46% in the Conjunction search and 39% in the Spatial Configuration search. This outperforms a baseline model that simply selects the closest target of any type, suggesting that search follows very stereotyped behavior especially when feature guidance is high.

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56.4101 **Feature priming facilitates target selection but does not modulate exogenous attentional shift** Amit Yashar[1](amit.yashar@nyu.edu), Alex White[1,3], Wanghaoming Fang[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of Psychology, University of Washington

Objective. People perform better in visual search when the target-defining feature repeats from the previous trial than when it changes across trials, due to automatic intertrial feature priming (IFP). Here, for the first time, we investigated the prevailing idea that IFP is due to stronger automatic capture of spatial attention toward the target when its feature repeats. We measured two effects with the same stimuli: the classic IFP effect during search for feature singletons, and the effect of relative location between an irrelevant singleton and a subsequent probe stimulus that must be discriminated. If the singleton exogenously captures attention, probe performance will be better when its location matches the singleton. If IFP modulates exogenous attention, the relative location effect will be larger when the singleton's color repeats than switches. Method. In each trial we presented a color singleton with either the same or a different color as in the previous trial. A Gabor (probe) followed the color singleton, either at the same or at a different location. The observers' task varied across pairs of trials between a probe and search task ('AABBAABB'). In search trials, observers discriminated the orientation of the singleton. In probe trials, observers discriminated the orientation of the probe. Results. In search trials that followed other search trials, color repetition facilitated singleton discrimination, demonstrating the classic IFP effect. In probe trials, performance was higher when the probe appeared at the same than at a different location as the singleton, demonstrating an exogenous attention shift toward the singleton. Critically, this location effect did not depend on whether the singleton's color repeated or switched from the previous trial. Conclusion. Our results suggest that, contrary to commonly accepted theory, recent experience does not modulate the automatic shift of attention to the target location. IFP and exogenous attention are independent.

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56.4102 **Expected visual search difficulty modulates the target representation** Joseph Schmidt[1](schmidtjoseph1@gmail.com), Gregory Zelinsky[2]; [1]Department of Psychology, University of Central Florida, [2]Department of Psychology, Stony Brook University

Does a target representation maintained in visual working memory (VWM) change with the expected difficulty of a search task? Previous work suggested that it does not (Gunseli, Olivers, & Meeter, 2014). We investigated this question, and how expected search difficulty impacts later search guidance, by having participants search for teddy bear targets among either other teddy bears (difficult search, high target-distractor similarity) or random non-bear objects (easy search, low target-distractor similarity). Target previews were identical in these two conditions. We measured target-related VWM load using contralateral delay activity (CDA), an event-related potential indicator of VWM load, after target designation but before search display onset. Expecting a difficult search produced larger CDA compared to when an easy search was expected ($p < .01$). Moreover, we found an interaction between time and task difficulty ($p < .01$). Comparing difficult to easy search, difficult search resulted in stronger CDA shortly after preview offset ($p \leq .05$), with this difference disappearing shortly before search onset ($p > .37$). We also found a cross-over interaction ($p = .05$) in CDA between expected search difficulty and search guidance. For difficult searches, when the initial search saccade was directed to the target (strong guidance) target-related VWM load was higher than when the initial search saccade was directed to a distractor (weak guidance). The opposite pattern was found for easy searches; target-related VWM load was higher for weak guidance trials. These findings demonstrate that target representations, and their subsequent impact on search guidance, are modulated by expected search difficulty. Constructing target representations may entail the extraction of a large pool of target details that are rapidly pruned away to create a smaller set of discriminative target features (Schmidt, MacNamara, Hajcak, & Zelinsky, 2014), suggesting that search target representations are fluid constructs that change over time to adapt to task demands.

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56.4103 **Control over target selection determines switch costs in multiple-target search.** Eduard Ort[1](e.ort@vu.nl), Johannes Fahrenfort[1], Christian Olivers[1]; [1]Cognitive Psychology, Vrije Universiteit Amsterdam

Visual selection of task-relevant objects is guided by a search template, a mental representation of a current search target that is assumed to be stored in working memory. Currently, it is debated whether one can have more than a single active search template that guides visual selection at any given moment. By demonstrating the absence of costs in fixation duration while scanning a search display for items that match one of two potential search templates, recent evidence suggests that one can look for multiple items simultaneously. Here, we investigated this issue further by applying a recently developed eye tracking paradigm. Crucially, subjects were instructed to look for two targets simultaneously while we manipulated the degree to which they had control over target selection. In a series of three experiments, we (1) show that switch costs disappear when instructing subjects to search for two target colors simultaneously, but only when subjects have full control over target selection (i.e., they choose at will which target color to select from the set of presented stimuli). However, (2) as soon as subjects lose control over the selection process, switch costs appear, showing that the emergence of switch costs depends on the degree to which one is in control of target selection. This suggests that the absence of switch costs in previous two-template experiments is caused by efficient template switching during search rather than having two templates active at the same time.

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56.4104 **Fitting two target templates into the focus of attention in a hybrid foraging task** Abla Alaoui Soce[1](aalaouisoce@partners.org), Matthew Cain[1,2], Jeremy Wolfe[1,3]; [1]Brigham and Women's Hospital, [2]U.S. Army Natick Soldier RD&E Center, [3]Harvard Medical School

In hybrid foraging, observers search visual arrays for multiple instances of multiple target types held in memory. Previous experiments have demonstrated that observers tend to pick items in "runs", repeatedly clicking on instances of one target instead of randomly searching amongst target types (Wolfe, et al., submitted). Switching between target types takes longer than selecting the same type again. Favoring runs is consistent with a model that maintains that multiple targets can be held in Activated Long Term Memory while a single item has special status as the current focus of attention in Working Memory. This WM template representation preferentially guides attention to more examples of its type (e.g., Wolfe, 2007; van Moorselaar, Theeuwes, & Olivers, 2014). To disrupt this single-item preferential guidance, we ran a hybrid foraging task with four target types where observers were required to pick a different target type on each selection. I.e., we forbade runs. This Forced Switch condition significantly slowed target collection (1563 msec/item) compared to a Forced Run condition (1151 msec/item) where observers were required to pick the same target type as the previous target selected whenever possible, ($t(11)=11.60$, $p< 0.0001$). Interestingly, observers in the Forced Switch condition adopted an "alternating run" strategy, switching between two targets more often than would be predicted by chance. This strategy improved efficiency: Alternating sequences (ABABAB) averaged 1269 msec/item, while mixed sequences (ABCBAD) averaged 1766 msec/item, ($t(11)=11.48$, $p< 0.0001$). This result suggests that it is either possible to maintain two items in the focus of attention, or to flexibly alternate between two items in the focus of attention. That is, in addition to the focus of attention and the list of target types in ALTM, another item can have a special, intermediate status as an "accessory" item that can be preferentially inserted into the focus of attention.

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56.4105 Evidence for salience-guided search in a fine-localization task Poutasi Urale[1](crimsonshinobi@gmail.com), Matt Oxner[1], William G Hayward[1]; [1]School of Psychology, University of Auckland

When is search for a target interrupted by unusual distractors? Recent work on this question is equivocal, with some studies finding distraction for both task-relevant and task-irrelevant stimulus dimensions, and other studies finding distraction effects only for task-relevant dimensions. The present study seeks to clarify this discrepancy by utilizing a novel point-and-click task asking participants to indicate the precise location of a target (an oblique line amongst vertical lines) using a computer mouse. Using spatial accuracy as a dependent variable, and displaying stimuli for only short durations, results from Experiment 1 show that accuracy is disrupted significantly more when a unique distractor is defined by a feature in a task-relevant (horizontal line) rather than task irrelevant (red vertical line) dimension. Experiments 2 and 3 looked at the effect of vertical red-line distractors when modulated in terms of frequency and salience, respectively, and found no effect of these modulations, but a significant effect of unique distractor presence versus absence. On the face of it, these results are irreconcilable with a dual-route account that assumes selection of a single dimension prior to search, and instead support an attention-contingent search guided by target salience (a la Wolfe's Guided Search Theory). In other words, it appears that fine localization not only requires focal attention but occurs through a summed activation map which takes input from multiple feature dimensions.

56.4106 Learning to shield visual search from salient distractors: qualitative differences in location probability cueing between same- and cross-dimensional distractors Marian Sauter[1,2](marian.sauter@psy.lmu.de), Michael Zehetleitner[3], Hermann Müller[1]; [1]Department of Psychology, Ludwig-Maximilians-Universität München, Munich, Germany, [2]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, Munich, Germany, [3]Department of Psychology, Catholic University of Eichstätt, Eichstätt, Germany

In visual singleton search, interference by salient singleton distractors can be more effectively overcome if they consistently appear at particular, i.e. 'frequent' – vs. 'infrequent' – display locations (Goschy et al., 2014). The present study investigated whether this "location probability cueing" effect is spatial in nature or dependent on the feature/dimension relationship of the distractor to the search target. Thirty-two observers searched for a slightly left- or right-tilted target bar among 35 vertically oriented gray bars. In half of the trials, one of the non-targets was a horizontal gray bar (i.e. same-dimension distractor). This compares with Goschy et al.'s (2014) study, in which the target was the same slightly tilted bar and the distractor a red (vertical) bar (i.e. cross-dimension distractor). The results revealed that (i) overall interference was higher with same- than with cross-dimension distractors (Cohen's d = 3.51 vs. d = 1.55); (ii) with same-dimension distractors, search was impaired for (orientation) targets appearing in the 'frequent' (orientation) distractor region, even when no distractor was actually present on a trial (d = .59) – an effect pattern not evident in the cross-dimension condition; (iii) with same-dimension distractors, although participants learn to shield search from distractors in the frequent region to some degree, the interference remains significant even after extended practice – in contrast to the cross-dimension condition where interference is effectively abolished after 8 blocks of 100 trials. This pattern of results suggests distractor shielding is critically dependent on the dimensional relationship between target and distractor: the target is spatially suppressed in the frequent distractor area only when it is defined in the same dimension as the distractor, but not when it is defined in a different dimension – consistent with the 'dimension-weighting account' of visual singleton search.

56.4107 Psychophysical Evaluation of Saliency Algorithms Calden Wloka[1,2](calden@cse.yorku.ca), Sang-Ah Yoo[3,2], Rakesh Sengupta[1], Toni Kunic[1,2], John Tsotsos[1,2]; [1]Electrical Engineering and Computer Science, Lassonde School of Engineering, York University, [2]Centre for Vision Research, York University, [3]Department of Psychology, York University

Significant effort has been spent evaluating the performance of saliency algorithms at predicting human fixations in natural images. However, many other aspects of human visual attention have received relatively little focus in the saliency literature but have been richly characterized by psychophysical investigations. In order to make use of this data, Bruce et al. (2015) have recommended the development of an axiomatic set of model constraints grounded in this body of psychophysical knowledge. We aim to provide a step towards this goal by linking human visual search response time to saliency algorithm output. Duncan and Humphreys (1989) theorized that subject response time in visual search tasks is correlated with similarity between search items (with search time increasing as targets become more similar to distractors). This result fits well with the widely held notion that saliency is largely driven by stimulus uniqueness, but has not been explicitly tested against the performance of saliency algorithms. To do so systematically, we need a well-characterized human performance curve for a given set of visual search stimuli. Arun (2012) produced a performance curve for oriented bars which shows the relationship between human response time and target-distractor orientation differences over the range 7-60º. Here we use Arun's stimuli as input to a range of current saliency algorithms and discover that performance falls into three broad categories: algorithms which cannot consistently find the target, those which consistently find the target but have no differentiated performace with target-distractor difference, and those which are able to deliver a human performance-like curve. In this way we provide a new performance criterion that is more closely aligned with the use of saliency as an early selection mechanism. Future work will look at the full set of Wolfe's (1998) features which can elicit efficient search for singleton targets.

Acknowledgement: NSERC

56.4108 Investigating dynamic feature prevalence and quitting thresholds in Multi-element Asynchronous Dynamic (MAD) search Collin Scarince[1](cscarinc@nmsu.edu), Michael Hout[1]; [1]New Mexico State University

While many visual search tasks require looking for stationary objects (e.g., finding mustard in the refrigerator), some search tasks are more complex, such as when security guards monitor multiple closed-circuit camera feeds. We utilized Multi-element Asynchronous Dynamic (MAD; Kunar & Watson, 2011) search displays to investigate search efficiency in dynamic settings. In Experiments 1a and 1b, participants searched categorically for target animals in displays with stationary, slowly blinking, and moving objects. We manipulated the rate at which targets possessed the various dynamic features (between-subjects) to determine if the relative occurrence of such features or the dynamic features themselves would have a dominant effect on search behavior (e.g., errors, RTs). Stimuli were photographs of animals in Experiment 1a (amid varying visual set sizes), and line drawings of similar categories (with a fixed set size) in Experiment 1b. We found that both dynamic features and their prevalence within target categories affected behavior, albeit somewhat inconsistently between experiments. In Experiment 2, participants completed blocks of MAD and fully static search (with trial-by-trial accuracy feedback); we examined search termination behavior surrounding missed targets (stimuli and set size were similar to Experiment 1b). Participants elicited higher miss rates in MAD search (compared to static search), but there were no significant differences in hit RTs between search displays or dynamic features. Misses in MAD search appear to be due largely to premature search termination errors, while misses in static search did not show this same early quitting trend. Together, we found that both specific dynamic features and their associations with targets affected search performance. Dynamic displays also resulted in more premature terminations compared to less complex displays. These results may inform training programs for operators that monitor complex displays, by emphasizing cognitive control to carefully rule out distractors and maintain an effective quitting threshold.

56.4109 The capacity of attentional templates Anna Grubert[1](a.grubert@bbk.ac.uk), Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London

During search for known objects, attentional selection is guided by target representations held in visual working memory. Such attentional templates are activated in a preparatory fashion prior to search and bias spatial attention towards objects with target-matching features. The capacity of such attentional templates remains contentious. Some studies have suggested that attentional control can be set for multiple features simultaneously, while others indicate that the capacity of attentional templates is more limited. We have previously found that the allocation of attention in visual search is slower and less target-selective when it is guided by multiple- relative to single-colour templates (Grubert & Eimer, 2013). More recently, we demonstrated that despite this efficiency cost of multiple-colour search, attention can be guided rapidly and independently by two simultaneously active target-colour templates (Grubert & Eimer, 2015). However, it may still be more difficult to exclude nontarget-colour distractors from attentional processing during multiple-colour relative to single-colour search. In a new study, we systematically tested this possibility with spatial cueing procedures similar to those used in an earlier behavioural study (Irons et al., 2012), and recorded N2pc components as ERP markers of attentional object selection. In different blocks, participants searched for targets defined by one constant colour or two different colours. Search displays were preceded by spatially uninformative colour singleton cues that could either match the current target colour(s) or a distractor colour. Both during one-colour and two-colour search, only target-matching cues triggered N2pc components and behavioural spatial cueing effects indicative of attentional capture. No such effects were found for distractor-colour cues, demonstrating that they were successfully excluded from attentional processing. Although there are qualitative differences between attentional guidance by single-colour versus multiple-colour templates, these results show that target templates can represent multiple colours simultaneously.

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56.4110 **The effect of intentional investment of effort on attentional orienting, executive control, and alerting** Motohiro Ito[1,2](moto.1100525@gmail.com), Jun Kawahara[2]; [1]Department of Psychology, Chukyo University, [2]Department of Psychology, Hokkaido University

It is clear that we can control our muscles intentionally, but can we also control our "cognitive muscles", i.e., attention? The present study examined whether participants were able to intentionally regulate attentional function while performing the Attention Network Test (ANT), which is designed to measure three major components of attention: orienting, executive control, and alerting. In this task, participants indicated the direction of a target arrow (left or right) preceded by a spatial cue. In Experiment 1, participants performed the ANT while investing either 50% or 100% of their attentional effort in separate experimental blocks. The results showed that mean reaction times in the 50% block were longer than those in the 100% block, indicating that participants complied with the instruction. The effects of alerting cues and flankers on alerting and executive conflict control function did not vary by condition. However, orienting function was affected by intention; the effect of spatial cueing was stronger in the 50% block than in the 100% block. To specify whether this difference in orienting function was due to functional enhancement in the 50% block or deterioration in the 100% block, we conducted Experiment 2 in which participants received no instruction with regard to the degree of effort they should expend (the neutral condition). The results indicated that the effect of spatial cueing on participants' orientating function was comparable to that observed in the 100% condition in Experiment 1, suggesting that the effect of instruction on orienting observed in Experiment 1 was due to functional enhancement in the 50% block. No such effects were found for conflict control and alerting function. The present study demonstrated that visual attention can be voluntarily controlled but in a counterintuitive direction: the orienting of attention improves when participants invest less cognitive effort.

56.4111 **Do Dyslexic Learners Benefit From Holistic Processing in a Comparative Visual Search Task?** Jiahui Wang[1](jwang01@ufl.edu), Matthew Schneps[2], Pavlo Antonenko[1], Marc Pomplun[2], Kara Dawson[1]; [1]Department of Educational Technology, College of Education, University of Florida, [2]Department of Computer Science, College of Science and Mathematics, University of Massachusetts - Boston

When perceiving visual stimuli, features are registered early, automatically, and in parallel, while objects are identified separately and at a later stage in processing (Treisman & Gelade, 1980). It has been suggested that people with dyslexia can develop enhanced peripheral vision to make use of a holistic strategy during visual search (Schneps, Brockmole, Sonnert, & Pomplun, 2012). This study explores whether dyslexic learners benefit from holistic strategies in a comparative visual search task. Participants included 18 individuals classified as dyslexic readers and 18 who were not. The experiment presented two blocks of 72 trials. Each trial consisted of two images to be compared side-by-side. Participants performed a conjunctive search to ascertain whether the two images were identical. In the first block, participants were provided no instruction regarding the visual strategy they were to employ. In the second block, participants were instructed to use a holistic viewing strategy – to "zone out" and perform the comparison by examining the whole screen at once. The results did not support the hypothesis of a dyslexic advantage when the holistic strategy was used. Using the holistic strategy, both groups scored 67.1% lower in accuracy ($\eta p2 = .671$, $F(1, 34) = 69.494$, $p < .001$) and reacted 54.7% faster ($\eta p2 = .547$, $F(1, 34) = 41.052$, $p < .001$), compared to accuracy and reaction time in the first block, controlling for the effect of learner group. Dyslexic learners spent 22% more time making the comparison decision in both conditions ($\eta p2 = .222$, $F(1, 34) = 9.678$, $p < .005$) than their non-dyslexic counterparts, controlling for the effect of strategy employed. It is possible that the instruction to pursue a holistic strategy hindered both dyslexic and non-dyslexic participants' ability to focus visual attention on the conjunctive features of objects, integrate objects into working memory and perform comparative organization.

56.4112 **Visual search for faces as a function of vertical and horizontal hemifield** Christophe Carlei[1](christophe.carlei@unige.ch), David Framorando[1], Nicolas Burra[1], Dirk Kerzel[1]; [1]Faculté de Psychologie et des Sciences de l'Éducation, Université de Genève, Switzerland

Asymmetries between left and right as well as upper and lower visual hemifield were investigated using a visual detection task with face stimuli. Participants had to detect a face with a gaze direction different from the remaining faces. Gaze was either direct (looking straight ahead) or indirect (looking sideways). The gaze singleton was either a direct gaze among faces with indirect gaze or an indirect gaze among faces with direct gaze. Participants were faster to respond when targets were presented in the upper left quadrant of the visual field compared to the other quadrants. This finding is in line with the literature. As participants have to process faces we expected them to use holistic processing, which is known to be better in the right hemisphere and should therefore lead to an advantage in the left hemifield. The upper visual field advantage was also expected because high-level processing such as object recognition or face processing is better in the upper visual field (Quek & Finkbeiner, 2015). Further, the left hemifield advantage disappeared when the same face stimuli were presented upside-down which confirms that the laterality effect is related to holistic processing of faces rather than to low-level stimulus characteristics. Additionally, the advantage of the upper visual field disappeared when the visual search task was made easier by presenting nontargets with closed eyes. In sum, our findings show that both laterality and elevation affect reaction times in search for a face singleton.

56.4113 **Scene Context Leads to Inattentional Scale Blindness during Search** Miguel Eckstein[1](eckstein@psych.ucsb.edu), Kathryn Koehler[1]; [1]Department of Psychological & Brain Sciences, University of California, Santa Barbara

Much work has demonstrated that scene context guides visual search toward likely target spatial locations and facilitates target detection. When the location of the target violates observer expectations then search performance deteriorates. Here, we hypothesize that scene context contributes to search in another distinct manner: scene context guides search toward likely spatial scales of the target. When targets are mis-scaled relative to other objects in the scene they will be harder to find even if they are more salient in isolation. Methods: Eye-tracked participants (n = 60) searched for different cued target objects in 42 scenes (yes/no task; 21 target present and 21 target absent scenes) presented for 1.5 s. Seven trials contained a target consistent in scale with the scene and another seven trials contained a scene with the target that was inconsistent in scale (increased size) relative to the background objects in the scene. To isolate effects of target/scene scale inconsistency from target size, seven additional trials contained a control version of the scene, cropped and magnified so that the target was the same size as in the mis-scaled scenes but consistent in scale with the scene. Images for the various trial types were counterbalanced across observers and trial order was randomized. Results: Hit rate for the target decreased from 0.816 to 0.685 ($p < 0.001$) when the target was mis-scaled relative to the scene. Hit rate in the control trials was 0.97 suggesting that it is not target size but inconsistency in scale with the scene which drives the detrimental effect on target detection. Eye movement analysis found very small differences (< ½ deg) in foveation of targets across scale consistent and inconsistent conditions. Conclusion: Our results strongly suggest that scene context not only guides search to likely possible target locations but also toward likely spatial scales.

Wednesday Morning Talks

Attention: Spatial

Wednesday, May 18, 8:15 - 9:45 am
Talk Session, Talk Room 1
Moderator: Tomas Knapen

61.11, *8:15 am* Attentional modulation of eye torsion responses.

Scott Stevenson[1](SBStevenson@uh.edu), Madhumitha Mahadevan[1], Jeffrey Mulligan[2]; [1]University of Houston College of Optometry, [2]NASA Ames Research Center

Eye movements generally have both reflexive and voluntary aspects, but torsional eye movements are usually thought of as a reflexive response to image rotation around the line of sight (torsional OKN) or to head roll (torsional VOR). In this study we asked whether torsional responses could be modulated by attention in a case where two stimuli rotated independently, and whether attention would influence the latency of responses. The display consisted of rear-projected radial "pinwheel" gratings, with an inner annulus segment extending from the center to 22 degrees eccentricity, and an outer annulus segment extending from 22 degrees out to 45 degrees eccentricity. The two segments rotated around the center in independent random walks, stepping randomly 4 degrees clockwise or counterclockwise at 60 Hz. Subjects were asked to attend to one or the other while keeping fixation steady at the center of the display. To encourage attention on one or the other segment of the display, subjects were asked to move a joystick in synchrony with the back and forth rotations of one part of the image while ignoring the other. Eye torsion was recorded with the scleral search coil technique, sampled at 500 Hz. All four subjects showed roughly 50% stronger torsion responses to the attended compared to unattended segments. Latency varied from 100 to 150 msec across subjects and was unchanged by attention. These findings suggest that attention can influence eye movement responses that are not typically under voluntary control.

61.12, *8:30 am* Attention-related BOLD modulation with and without superior colliculus inactivation

Anil Bollimunta[1](anilbollimunta@gmail.com), Amarender Bogadhi[1], David Leopold[2], Richard Krauzlis[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health, [2]Laboratory of Neuropsychology, National Institute of Mental Health, National Institutes of Health

The superior colliculus (SC) contributes to visual spatial attention through mechanisms that can be dissociated from the classic attention-related modulation in visual cortex (Zenon & Krauzlis, 2012). To identify brain regions that might be part of the SC attention network, we have conducted fMRI in a monkey performing a spatial attention task, with and without SC inactivation. Imaging runs contained three types of blocks: Baseline (B), Foveal Attention (FA) and Peripheral Attention (PA), indicated to the monkey by the color of the fixation spot. In B block trials, the relevant stimulus was a central fixation point that dimmed at randomized times. FA block trials were similar to B block trials but added a peripheral motion-change stimulus as an irrelevant distracter. In PA block trials, the fixation point did not dim and the peripheral motion-change was the relevant stimulus. The monkey's task, in each block, was to maintain central fixation and to report the relevant stimulus change by releasing a lever to get a juice reward. In each anatomically defined ROI, we identified voxels with significant differences between PA and B blocks, and calculated an attention modulation index (AMI) for each of these voxels based on the %change in BOLD for PA and FA blocks. During SC inactivation, several cortical areas (V1, MT/MST, LIP and FEF) showed significant attentional modulation, with computed AMIs comparable to control values, despite the presence of significant performance deficits in the attention task. However, attention-related modulation was abolished in cortical area FST in the superior temporal sulcus, and dramatically reduced in the caudate, a subcortical input nucleus for the basal ganglia. The results suggest that the SC contributes to attention through a circuit involving cortical area FST and parts of the basal ganglia, highlighting the possible role of subcortical decision-making mechanisms in the control of attention.

61.13, *8:45 am* Attention Improves Stimulus Encoding in Early Visual Cortex

Daniel van Es[1](daan.van.es@gmail.com), Tomas Knapen[1]; [1]Vrije Universiteit Amsterdam

The human visual system encodes spatial relations along the anatomical scaffold of retinotopic organisation, yet top-down control can flexibly change the encoding of visual space. We investigated this flexible encoding of space by means of population receptive field (pRF) mapping. In separate conditions, participants performed a titrated two-alternative forced choice task on either fixation luminance, or the color or speed of elements in a bar aperture systematically traversing the visual field. Single-voxel pRF parameters were fit for each of the conditions, and their spatial characteristics were compared across conditions and retinotopic regions. Over and above changes in pRF amplitudes, voxels' preferred visual-field position and size changed as a result of stimulus-based attention. Notably, visual-field position changes were restricted to radial movement, i.e. to changes in eccentricity. The sign of changes in eccentricity depended on pRF eccentricity during fixation; central pRFs migrate outward, whereas peripheral pRFs move inward. Changes in size were strongly correlated with these changes in position. That is, outward migration was tied to an increase in size, whereas inwardly migrating pRFs showed decreases in size. We then explored how these pRF dynamics affect stimulus representation at the retinotopic level by decoding the spatial signature of the stimulus based on pRF parameters and BOLD amplitudes. This approach showed that the aggregate effect of spatial attention on a population-level is an increase in the spatial fidelity of the stimulus representation, regardless of the sign of underlying pRF size changes. We show that attention changes pRF positions radially, and that both size increases and decreases may result in increased fidelity of the encoding of spatial stimulus characteristics. These results elucidate how attention changes visual spatial processing.

61.14, *9:00 am* Reconstruction of the attentional priority representation of faces from V1 activities

Ce Mo[1](mocheck@sina.com), Dongjun He[2], Fang Fang[1,2,3]; [1]Peking-Tsinghua Center for Life Sciences, Peking University, [2]Department of Psychology and Key Laboratory of Machine Perception (Ministry of Education), Peking University, [3]IDG/McGovern Institute for Brain Research, Peking University

Priority maps are real-time representations of the behavioral salience of locations in the visual field, which guide the deployment of attention and the planning of saccades. Here, we reconstructed the priority map of faces from BOLD signals in V1 by quantifying the spatial profile of neural activity using population receptive field (pRF) mapping. We used images of upright and inverted faces. Phase-scrambled faces were also used as baseline. In the behavioral experiment, subjects viewed the images and performed a one-back memory task on the stimuli. We recorded the target location of subjects' first saccade for each of the images. In the fMRI experiment, subjects performed a one-back memory task in which subjects needed to attend to the stimuli or a RSVP task on a central letter stream in which their attention was directed away from the stimuli. To reconstruct the priority map, we measured the attention effect size by comparing the BOLD signals in the two task conditions for each voxel in V1 and summated the voxel-wise pRF profiles weighted by the attention effect size measurements. We found that the reconstructed map was highly consistent with the spatial distribution of the target location of the first saccade. Notably, the high-priority regions in the reconstructed map for the upright faces unambiguously corresponded to the facial areas carrying the critical identity information, namely the eyes, the nose, and the mouth, while no such a systematic correspondence was found for the inverted faces. These results suggest that the priority map for natural face stimuli might be located in V1. Our findings thus make headways towards unraveling the neural mechanisms on the generation of the priority map.

61.15, *9:15 am* Comparing Efficiencies in Estimating Centroids and Judging Numerosity

Matthew Inverso[1](minverso@uci.edu), Charles Chubb[2], Charles Wright[3], Richard Shiffrin[4], George Sperling[5]; [1]University of California, Irvine, [2]University of California, Irvine, [3]University of California, Irvine, [4]Indiana University, Bloomington, [5]University of California, Irvine

How efficiently can the visual system use stimulus information in a briefly viewed cloud of dots for two different purposes: judging the number of dots in the cloud (numerosity) versus estimating the cloud's center-of-gravity (its centroid)? These two statistical summary statistics can be estimated rapidly and quite accurately even in very brief stimulus exposures. As judging numerosity requires only knowing the presence of a dot, whereas estimating

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a centroid requires knowing both a dot's presence and position, we might expect numerosity judgments to be more efficient that centroid estimations. Methods. Subjects viewed a cloud of black dots drawn from a circular, bivariate Gaussian distribution. For N = 9 or 12, the cloud contained either N (on half the trials) or N+1 dots. In the "Numerosity Task," on each trial, the participant judged whether there were N vs N+1 dots. In the "Centroid Task," on each trial, the participant strove to mouse-click the centroid of the dot cloud. Results. To compare numerosity and centroid performances, we assume that all errors (in both tasks) result from random decimation of the display. Specifically, for each task, we determined the probability E ("Efficiency") for which the participant's performance matched an ideal detector's performance derived by removing dots independently from the display with probability 1- E. When displays comprised either 9 dots or 10, Efficiency was approximately equal in the two tasks; when displays comprised 12 dots or 13, Efficiency was slightly higher estimating centroids task than judging numerosity. Conclusion. Surpisingly, efficiency is equal or higher in estimating centroids than judging numerosity suggesting that position information required for judging centroids is essentially free, i.e., it is very accurate (i.e., position error is small relative to other errors) and that it doesn't require resources that are used for representing the presence of dots.

61.16, *9:30 am* **Adding Shape to Saliency: A Proto-object Saliency Map for Predicting Fixations during Scene Viewing** Yupei Chen[1](-psycyp@gmail.com), Chen-Ping Yu[2], Gregory Zelinsky[1,2]; [1]Department of Psychology, [2]Department of Computer Science

Traditional saliency models predict fixations during scene viewing by computing local contrast between low-level color, intensity and orientation features; the higher the summed contrast the greater the probability of fixation. Evidence also suggests that high-level properties of objects are predictive of fixation locations. We attempt fixation prediction from proto-objects (POs), a mid-level representation existing between features and objects. Using our previously-reported proto-object model (Yu et. al., 2014, JoV), we segmented 384 images of real-world scenes into proto-objects, fragments of visual space, at multiple resolutions (feature-space bandwidths). We then built from these segmentations a saliency map by computing feature contrast between each proto-object and its local neighbors using intensity, color, orientation, and now, size and shape features. Center-surround size contrast was computed by comparing pixel area between a given proto-object and each "surrounding" neighbor. To compute shape contrast we first normalized a proto-object and a neighbor to have the same area, aligned them based on maximum area-overlap, then counted the number of pixels in the overlapping area (divided by the union of the areas), with a smaller overlap over neighbors coding a higher contrast. Doing this relative to each proto-object, then combining contrast signals across features and resolutions, generates a proto-object saliency map, which we used to predict the fixation behavior of 12 participants freely viewing the same scenes (each for 3 seconds) in anticipation of a memory test. We found that our proto-object saliency map predicted fixations as well or better than an Itti-Koch saliency model, and was nearly as predictive as the upper-limit defined by a Subject model obtained using the leave-one-out method. We conclude that size and shape features, quantified in terms of proto-objects, are used to guide overt visual attention, and that saliency-based models of fixation prediction need to recognize the importance of these mid-level visual features.

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Object Recognition: Neural correlates and cognition

Wednesday, May 18, 8:15 - 10:00 am
Talk Session, Talk Room 2
Moderator: Peter Bex

61.21, *8:15 am* **Visual cortex overlap between hand and tool responses does not require having hands** Ella Striem-Amit[1,3](s-triemit@gmail.com), Gilles Vannuscorps[1,2,3], Alfonso Caramazza[1,2]; [1]Department of Psychology, Harvard University, Cambridge, MA 02138 USA, [2]Center for Mind/Brain Sciences, University of Trento, 38068 Rovereto, Italy, [3]These authors contributed equally to this work

The lateral occipital temporal cortex (LOTC) shows spatially overlapping responses for viewing hands and tools. This overlap is particularly interesting given that the two are functionally linked in object manipulation, giving rise to potential explanations based on connectivity constraints linking shape properties to motor affordances and action. Here we investigated the role of motor experience in driving the organization of this region, by studying five individuals born without developed hands (dysmelic subjects), who use tools with their feet. In an fMRI experiment we presented pictures of tools, non manipulable artifacts, hands and feet to the dysmelic subjects and to typically developed controls. We found that some dysmelic subjects, like the majority of the controls, showed an overlap between hand- and tool-selective responses in LOTC, refuting an explanation based solely on visuo-motor representations of actions. Instead, this suggests the region's overlap may develop based on object co-occurrence in visual experience alone. However, since both body and object responses were also observed in LOTC in people born blind, the current findings add support to a modality-independent organization model, based on connectivity constraints, without reliance on any specific sensory or motor experience. Of interest is the additional finding that some dysplasic subjects also had an overlap of foot- and tool-selective responses in LOTC, suggesting a certain level of plasticity to this principle, based on one's own sensory and motor experience.

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61.22, *8:30 am* **Investigating the temporal properties of visual object processing using a multivariate analysis of EEG data.** David Coggan[1](ddc506@york.ac.uk), Timothy Andrews[1], Daniel Baker[1]; [1]Department of Psychology, University of York, UK

An understanding of human object recognition requires combining both spatial and temporal information about neural activity. Previous studies using fMRI have found distinct spatial patterns of response in the ventral visual pathway. However, the temporal dynamics of these patterns of response is less clear. Here, we acquired human electroencephalography (EEG) responses to images from different object categories (bottle, face, house). Our aims were to determine (1) whether there are distinct patterns of EEG response to different object categories; (2) the temporal properties of these patterns and (3) the extent to which these patterns are based on low-level image properties. Participants viewed images of bottles, faces and houses while EEG data was acquired from 64 electrodes. A correlation-based multivariate pattern analysis revealed distinct patterns of response across electrodes to different object categories that emerged at approximately 90 msec and remained distinct until approximately 600 msec after stimulus onset. Next, we asked whether these patterns of neural response could be explained by selectivity to more basic properties of the stimulus. To address this question, we measured patterns of EEG response to phase-scrambled images. Our rationale for using scrambled images is that they have many of the image properties found in intact images, but do not convey any categorical or semantic information. Again, distinct patterns of response to scrambled images from different object categories emerged approximately 70-100 msec after stimulus onset. Moreover, the patterns of neural response to scrambled images from each object category were similar to the patterns of response for intact images. However, distinct patterns to scrambled images were only evident until approximately 300-450 msec after stimulus onset. Together, these results provide new insights into the temporal dynamics of object processing in the human brain.

61.23, *8:45 am* **Neural representation of object orientation reveals dissociation between MVPA and Repetition Suppression** Miles Hatfield[1](Mileshatfield89@gmail.com), Michael McCloskey[1], Soojin Park[1]; [1]Department of Cognitive Science, Johns Hopkins University

How is object orientation represented in the brain? Behavioral studies reveal that certain orientations are reliably more confusable than others. Using fMRI, we ask whether object-selective cortex (LO) represents these confusability relations, and if so, how they are realized neurally. Specifically, we assess whether more confusable orientations are represented more similarly in LO, while comparing two different metrics of neural similarity: MVPA and Repetition Suppression. Participants (N=11) viewed a counterbalanced stream of 16 orientations of an object while performing a task to ensure attention. Using a continuous carry-over design, we simultaneously measured the adapting effect (Repetition Suppression) as well as the multi-voxel pattern similarity (MVPA) between orientations. To estimate whether behavioral confusability is reflected in neural similarity, we modeled both Repetition Suppression and MVPA measures as a function of the behavioral confusability between orientations (empirically defined from highly reliable confusion errors observed in a previous experiment, Gregory & McCloskey, 2010). Using regression-based representational similarity analyses, we found that the behavioral confusability of orientations predicted MVPA pattern similarity in LO (β = 3.09, p< .0001, Permutation tests) even after accounting for pixel-based image similarities to which V1 was highly sensitive. By contrast, Repetition Suppression was not sensitive to the confusability of orientations (β = -.32, p=.55). These results suggest that LO represents the confusability of orientations in the similarity of across-voxel patterns, but not in the degree of Repetition Suppression, suggesting that these two fMRI measures reflect different aspects of neural similarity. To account for the differences between Repetition Suppression and MVPA, we propose a novel hypothesis on which MVPA-similarity reflects the topographical distribution of neuronal populations, whereas Repetition Suppression depends on repeated activation of neuronal populations. We show how these measures provide complementary information about neural representations, together allowing for richer conclusions than possible with either method alone.

61.24, *9:00 am* **The serial dependence of object perception is independent of decision** Alina Liberman[1](alinal@berkeley.edu), David Whitney[1, 2]; [1]Helen Wills Neuroscience Institute, UC Berkeley, [2]Dept. of Psychology, UC Berkeley

Object identities appear stable and continuous over time despite visual noise, disruptions in visibility, and constantly changing visual input. Recent results have demonstrated that the perception of stimuli such as orientation, facial identity, and facial expression is systematically biased (i.e., pulled) toward visual input from the recent past (Fischer & Whitney, 2014; Cicchini et al., 2014; Liberman et al. 2014; Liberman & Whitney, VSS 2015). The spatio-temporal region over which current orientations or face identities are pulled by previous orientations or identities, respectively, is known as the continuity field. This serial dependence of perception could contribute to the visual stability of objects over short time periods, but it is unknown whether serial dependence can occur for multiple object dimensions in parallel and whether it requires a decision. Here, we tested whether the continuity field plays a role in maintaining the stability of facial expression and identity simultaneously. Subjects saw a series of faces that varied randomly in both identity and expression. Before subjects saw each face, they were cued to which of the two facial dimensions they should attend to (identity or expression). Subjects then had to match either the expression or identity of a test face to the target dimension they had previously attended. Subjects made consistent errors when reporting the perceived expression or identity of the target face, seeing it as more similar to the facial expression or identity presented on the previous trial, respectively. Furthermore, this perceptual pull within a facial dimension occurred regardless of which dimension subjects attended to on the previous trial. Perceived expression or identity was pulled toward previous expressions or identities, independent of any decisions or judgments made on previous trials. These results indicate that the continuity field can operate on multiple facial dimensions in parallel in order to maintain perceived object stability.

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61.25, *9:15 am* **Reading rainbows: Measuring the dynamics of word processing** Anna Kosovicheva[1](akosov@neu.edu), Peter Bex[1]; [1]Department of Psychology, Northeastern University

What is the delay in processing a word you have just read, and how does it change through the course of a sentence? To answer these questions, we developed a new paradigm for measuring the time course of semantic processing with respect to fixations while reading. On each trial, observers read a four-word sentence that changed color continuously through a circular set of hues. Observers were then shown a response palette arranged in an annulus and instructed to select the perceived color of a randomly selected (precued) word at the time that they read it. In addition, observers categorized the statement as either true or false which necessitated encoding all four words. Trial duration was adaptively controlled to ensure that subjects had sufficient time to read the sentence, while minimizing re-fixations. In a non-reading baseline condition, sentences were replaced with horizontal bars, divided into outlined regions corresponding to locations of previously seen words. Observers reproduced their eye movements from the reading task by tracking a crosshair positioned at previously fixated locations. At the end of the trial, subjects performed the same color reporting task. For both the reading and non-reading conditions, we measured the latency between the beginning of the observer's first fixation on the word and the time point in the trial corresponding to the reported color. Results showed distinct patterns of temporal lags in the two conditions—while response delays in the non-reading task remained constant as a function of their position the sequence, delays in the reading task were greater for words earlier in the sentence than for words later in the sentence. Together, our results demonstrate a new method for examining the dynamics of information processing, and point to contextual influences on semantic processing delays with respect to fixations during reading.

61.26, *9:30 am* **Is dyslexia due to deficits in high-level visual processing? Face and object recognition problems in dyslexia** Heida Sigurdardottir[1](heidamaria@gmail.com), Eysteinn Ívarsson[1], Kristjana Kristinsdóttir[1], Árni Kristjánsson[1]; [1]Department of Psychology, School of Health Sciences, University of Iceland

Previous research has consistenly shown that the left fusiform gyrus, a part of the ventral visual stream, is hypoactive in dyslexic children and adults. The region is involved in the perception of words, faces, and other homogeneous or complex objects. We therefore investigated whether dyslexics show abnormal facial recognition and within-category recognition of other visual objects. We tested 20 dyslexic adults and 20 typical readers (matched for age, gender, and education) on several tasks that rely on high level ventral stream regions: The Cambridge Face Memory Test (CFMT; upright/inverted faces), the Vanderbilt Holistic Face Processing Test (VHFPT), and the Vanderbilt Expertise Test (VET). All tests call for fine shape discriminations of objects within a category. We also included a control test involving color recognition. For dyslexic participants, but not typical readers, performance was significantly poorer than previously reported average performance on the CFMT (upright faces). Compared to their matched typical readers, dyslexics also found it harder to recognize faces (CFMT). While dyslexics had facial recognition problems, they did not show atypical holistic processing of faces, one of the hallmarks of face processing (as measured by the face inversion effect and the VHFPT).This is consistent with their left fusiform hypoactivation; the right hemisphere is generally considered to be more involved in holistic processing. Additionally, dyslexics' within-category recognition of non-face objects (VET) was impaired, compared to typical readers. Conversely, no consistent differences were found on the color recognition control test that shares many important components with both the CFMT and the VET. The results support the intriquing proposal that difficulties in reading in dyslexia might be the most salient manifestation of a more general high-level visual deficit.

Acknowledgement: Postdoctoral Grant, Recruitment Fund of the University of Iceland

61.27, *9:45 am* **Cortical thickness of functionally-defined visual areas in schizophrenia and bipolar disorder** Eric Reavis[1,2](ereavis@ucla.edu), Junghee Lee[1,2], Jonathan Wynn[1,2], Stephen Engel[3], Amy Jimenez[2,1], Aaron McNair[2], Eugene Kutasevich[2,4], Michael Green[1,2]; [1]Semel Institute for Neuroscience and Human Behavior, University of California, Los Angeles, [2]Desert Pacific Mental Illness Research, Education, and Clinical Center, Greater Los Angeles Veterans Affairs Healthcare System, [3]Department of Psychology, University of Minnesota, [4]Department of Psychology, Mount Saint Mary's University

Patients with schizophrenia show specific abnormalities in visual perception, and patients with bipolar disorder may have related perceptual deficits. During tasks that highlight perceptual dysfunction (e.g., backward masking, contour integration), patients with schizophrenia show abnormal activity in visual brain areas including the Lateral Occipital Complex (LOC) and early retinotopic cortex. It is unclear whether the anatomical structure of such visual areas is atypical in schizophrenia and bipolar disorder. Using structural and functional MRI, we compared the cortical thickness of LOC and early retinotopic cortex in patients with schizophrenia (N=33), patients with bipolar disorder (N=31), and healthy controls (N=30). We identified LOC and early retinotopic cortex individually for each participant using functional localizers (objects vs. scrambled objects and phase-encoded retinotopic mapping, respectively). We measured the cortical thickness of each of those functionally-defined regions of interest (ROIs) using high-resolution anatomical scans processed with FreeSurfer 5.3.0 (Martinos Center for Biomedical Imaging, Charlestown, Mass.). In both LOC and early retinotopic cortex, patients with schizophrenia had the thinnest cortex, healthy controls had the thickest cortex, and bipolar disorder patients had intermediate cortical thickness. Within several sub-regions of early retinotopic cortex -- V1, V2, and V3 -- there was a trend for the same pattern of group differences. However, a control region, motor cortex, did not show this pattern of group differences. Although patients were on clinically determined doses of medication, there were no significant relationships between medication dosage and the cortical thickness of any ROI in either patient group. The thickness differences that exist in LOC and early retinotopic cortex could be an anatomical substrate for abnormalities in visual processing that have been identified with both neural and behavioral measures in schizophrenia and other severe mental illnesses.

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Visual Search: Attention

Wednesday, May 18, 11:00 am - 12:45 pm
Talk Session, Talk Room 1
Moderator: Joo-Hyun Song

62.11, *11:00 am* A detailed comparison of optimality and simplicity in visual search

Wei Ji Ma[1,2](weijima@nyu.edu), Shan Shen[2]; [1]Dept. of Psychology and Center for Neural Science, New York University, [2]Dept. of Neuroscience, Baylor College of Medicine

Two prominent ideas in the study of decision-making have been that organisms behave near-optimally, and that they use simple heuristic rules. These principles might be operating in different types of tasks, but this possibility cannot be fully investigated without a direct, rigorous comparison within a single task. Such a comparison was lacking in most previous studies, because the optimal decision rule was simple, no simple suboptimal rules were considered, it was unclear what was optimal, or a simple rule could closely approximate the optimal rule. We used a visual search task in which the optimal decision rule is well-defined and complex, and makes qualitatively distinct predictions from many simple suboptimal rules. Set size was 4. Each search display contained one target and three distractors. The distractors shared the same orientation. The target orientation and the common distractor orientation were independently drawn from the same distribution. The observer reported the direction of tilt of the target. All simple rules tested fail to describe human behavior. The optimal rule accounts well for the data, and several complex suboptimal rules are indistinguishable from the optimal rule. In a second experiment, we completely withheld trial-to-trial feedback and found that the conclusions remained unchanged, suggesting that visual computation in this task is not only optimal but also relies on an implicit representation of uncertainty. In both experiments, we found evidence that the optimal model is close to the (unknown) true model: first, the better the trial-to-trial predictions of a suboptimal model agree with those of the optimal model, the better that suboptimal model fits; second, an estimate of the Kullback-Leibler divergence between the optimal model and the true model is not significantly different from zero. Beyond the specifics of the task, these novel "absolute goodness-of-fit" tests could likely benefit many areas of vision science.

62.12, *11:15 am* Misguided: how knowing the orientation of the target can make you worse at visual search

Johan Hulleman[1](johan.hulleman@manchester.ac.uk); [1]School of Psychological Sciences, The University of Manchester

Hulleman & Olivers (BBS, in press) have proposed a fixation-based theoretical framework for visual search, where performance is determined by the Functional Visual Field (FVF). Target-present decisions are based on statistics pooled across the FVF. In easier tasks the FVF covers multiple items, whereas the FVF reduces to a single item in very difficult search. This framework predicts qualitative differences in guidance by orientation. For difficult search, knowing the target orientation should help, since saccades to individual ineligible items can be avoided. For easier search this is not possible and the presence of differently orientated, ineligible items in the FVF may interfere with the computation of the pooled statistics. Sixteen participants searched for a T amongst L (medium search) and for a specific configuration of squares (difficult search), in counterbalanced blocks. In the 100% eligibility condition all items had the same orientation as the target. In the 50% eligibility condition only half of the items shared the target orientation. The other half could be rejected based on their different orientation. There were three display sizes: 6, 12 and 18 items. For difficult search, knowing the orientation of the target improved performance when eligibility went from 100% to 50%. Search slopes decreased both on target-absent trials and on target-present trials. For medium search however, performance deteriorated. The slopes increased both on target-present and on target-absent trials. So, orientation knowledge made difficult search better, but made medium search worse. This supports Hulleman & Olivers' framework. In very difficult search the FVF encompasses only a single item. This allows the use of orientation knowledge to avoid saccades to ineligible items. In medium search, the FVF encompasses multiple items. This means that it is not possible to selectively target eligible items, since several of the other items that fall within the FVF may be ineligible.

62.13, *11:30 am* Impact of conscious versus unconscious distractors in pop-out visual search

Christine Gamble[1](christine_gamble@brown.edu), Joo-Hyun Song[1,2]; [1]Department of Cognitive, Linguistic and Psychological Sciences, Brown University, [2]Brown Institute for Brain Science, Brown University

It has consistently been demonstrated that in singleton pop-out search, increasing the number of homogenous distractors reduces reaction time (RT) for target discrimination. This is thought to be due to larger overall set sizes facilitating the grouping of visual stimuli. However, it is currently unknown how unconscious visual stimuli compare to conscious stimuli in visual search, and the degree to which conscious awareness is necessary for grouping and singleton pop-out. In the present study, we directly compared the influence of conscious versus unconscious distractor number on singleton pop-out in visual search. In order to establish the facilitation of pop-out via conscious distractor grouping, we presented participants with a target of either red or green, and between 3 and 20 distractors of the alternate color. To determine the influence of unconscious distractors on pop-out, we replicated these conditions using a continuous flash suppression (CFS) paradigm designed to suppress awareness of all but 2 of the distractors. We measured participants' RT to correctly identify the shape of the singleton target via button-press, and compared these RTs across distractor number and conscious versus unconscious distractor presentation. Consistent with past visual search studies, we found that increasing the number of conscious distractors caused a linear decrease in RT, consistent with search facilitation via grouping. However, unconscious distractor presentation had the opposite effect, with increasing numbers leading to an overall increase in RT. This indicates that participants still processed unconscious distractors despite a lack of conscious visual awareness. However, rather than facilitating visual search as conscious distractors do, unconscious distractors interfered with visual search, likely due to a failure of grouping. This suggests that in visual search unconscious stimuli are processed inherently differently from conscious stimuli, and that stimulus grouping may be a primarily conscious process.

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62.14, *11:45 am* The Influence of Visual Clutter on Search Guidance with Complex Scenes

Arturo Deza[1](deza@dyns.ucsb.edu), Grant Taylor[2], Miguel Eckstein[1]; [1]University of California, Santa Barbara, [2]U.S. Army Aviation Development Directorate

Previous studies have proposed image based measures of clutter and correlated them to subjective judgments of perceptual clutter (Yu et al., 2014) or threshold contrasts during a search task (Rosenholtz et al., 2007). Here we evaluate multiple clutter metrics (Feature Congestion, FC; Subband Entropy, SE, Rosenholtz et al., 2005; Freeman & Simoncelli, 1995; Proto-Object Segmentation, PS, Yu et al., 2014) and correlate them with the time required for observers to fixate a searched target. In addition, we evaluate the influence of clutter on detectability as a function of retinal eccentricity of the target. Methods: In experiment 1, twelve observers searched with eye movements (free search) for a target (any person; 50 % probability present) in video stimuli rendered from a virtual environment, presented at 200, 400, 800, 1800, or 3200 ms. In experiment 2, twelve observers maintained their gaze on a fixation (forced fixation) with the target appearing at 4 different cued retinal eccentricities (1, 4, 9, and 15 deg) and with varying presentation times (half of free search). For both experiments, observers reported with a 1-10 rating of their confidence about the presence of the target. Results: Times for target foveation in experiment 1 were consistently longer for high clutter scenes irrespective of the metrics (320 ms high clutter vs. 260 ms low clutter), but PS resulted in the highest correlation with clutter ($r_{FC} = 0.336$; $r_{SE} = 0.261$; $r_{PS} = 0.565$ for 3200 ms). In experiment 2, a half split analysis (high vs. low clutter) shows clutter degrades detectability only beyond 9 deg. target eccentricity. Finally, the PS clutter metric also resulted in the highest negative correlation with hit rate ($r = 0.733$). Conclusions: Our results show the effects of clutter on eye movement guidance and target detectability, and suggest that the ProtoObject Segmentation metric can best predict such detriments.

62.15, *12:00 pm* Search excludes irrelevant regions in immersive environments

Chia-Ling Li[1](sariel.cl.li@utexas.edu), Maria Aivar[2], Matthew Tong[3], Mary Hayhoe[3]; [1]Institute for Neuroscience, University of Texas at Austin, [2]Facultad de Psicología, Universidad Autónoma de Madrid, [3]Center for Perceptual Systems, University of Texas at Austin

The role of memory in guiding attention in real scenes is complex. One way that experience might guide search is by reducing the areas of the scene searched and directing search away from irrelevant regions (Neider and Zelinsky, 2008, Wolfe et al., 2011). We explored whether this is a significant factor in guiding search in immersive natural environments. We performed the search task in a 3D virtual environment, as well as in a 2D version that was parallel in task structure. Subjects searched for targets that were located on one of four surfaces in either of two rooms. We investigated the source of improvement from learning the space at both global and local levels: i) which room contains the target and ii) in which part of that room the target is located. We found that the probability of choosing the correct room to search on first entry is higher in 3D than in 2D, and improves in both cases. The number of room entries required to find the targets was also lower in 3D and decreased over episodes. More fixations inside the rooms are directed to surfaces that potentially contain targets in both 2D and 3D (increased from 60% to 87% of fixations after 24 trials in 3D). Surface fixations even early in the experiment indicate the influence of prior scene knowledge. Together these results indicate that memory representations facilitate search by restricting attention to the relevant parts of the environment while excluding the irrelevant parts at the global level (choosing the correct room) and also at the local level (looking at relevant regions inside the room). In addition, the data also suggest that global memory is used more in 3D, potentially because of the higher energetic or temporal cost of changing the region to be searched.

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62.16, *12:15 pm* **Is search priming reflected in BOLD repetition suppression?** Manje Brinkhuis[1,2](manjebrinkhuis@gmail.com), Arni Kristjansson[1], Jan Brascamp[2,3]; [1]Department of Psychology, University of Iceland, Oddi við Suðurgötu, IS-101 Reykjavík, Iceland, [2]Helmholtz Institute and Department of Psychology, Utrecht University, Heidelberglaan 1, 3584CS, [3]Department of Psychology, Michigan State University, East Lansing, MI 48823, U.S.A.

In priming of visual search, response times decrease when the target defining feature or target location repeat across two consecutive search trials. These examples of lag-one priming have been linked to suppression in the fMRI BOLD-response in the frontoparietal attention network, and in regions within visual cortex (Kristjansson et al., 2007). However, similar results have also been interpreted as response enhancement associated with reversals of target and distractor properties, rather than as suppression associated with search priming (Rorden et al. 2011). Another typical aspect of search priming is that response-time effects from a single trial decay exponentially across 5 to 8 trials (Martini, 2010). If BOLD repetition suppression does represent a physiological correlate of search priming, then it should follow a similar decay. Here we test this prediction. First we aimed to replicate the findings of decaying behavioral priming (Martini) and lag-one BOLD repetition suppression (Kristjansson et al). By independently varying target color, location and response defining feature in a priming-of-pop-out task we assessed the individual effects of these factors on subsequent trials. We confirmed Martini's exponential signature of search priming for all three target properties, and our fMRI findings are in correspondence with those of Kristjansson et al. for repetition of color and location. Moreover, BOLD repetition suppression was found for the response-defining feature. Next, we assessed the time course of BOLD repetition suppression across trials, hypothesizing that the priming decay seen behaviorally will be reflected in the BOLD-response in brain areas involved in this priming. Indeed, we find BOLD repetition suppression that changes in magnitude across trials in intraparietal sulcus and frontal eye fields among other areas. We suggest that this time course of repetition suppression reflects the neural basis of search priming.

62.17, *12:30 pm* **The attentional fields of visual search in simultanagnosia and healthy individuals: How object and space attention interact** Aarlenne Khan[1](aarlennek@gmail.com), Myriam Prost-Lefebvre[2], Romeo Salemme[2], Gunnar Blohm[3], Yves Rossetti[2], Laure Pisella[2]; [1]School of Optometry, University of Montreal, Montreal, QC, Canada, [2]ImpAct – Lyon Neuroscience Research Center, Inserm U1028, CNRS UMR 5292, Bron, France, [3]Centre for Neuroscience Studies, Queen's University, Kingston, ON, Canada

Simultanagnosia is a deficit in which patients are unable to perceive multiple objects simultaneously. To date, it remains disputed whether this deficit results from disrupted object or space perception. We asked both healthy participants as well as a patient with simultanagnosia to perform different visual search tasks (both pop-out and serial) of variable difficulty using different gaze-contingent visible window sizes. This allowed us to determine the size of the attentional span used for each visual search task; only visible windows that were smaller than the specific attentional span used for the task resulted in a cost in reaction times to find the search target. To determine whether this attentional span varied according to object or space, we also modulated the number of objects (target and distracters). For healthy participants, we found that each visual search task was performed with a specific attentional span depending on the difficulty of visual object processing but not on the number of objects falling within this space. For the patient with simultanagnosia, we found a reduced attentional span compared to controls but only for search tasks with objects that were made up of separable features. This did not vary according to the number of objects. Thus, we conclude that bilateral damage to the superior parietal lobule (SPL) impairs the spatial integration of separable features (within-object processing), shrinking the attentional span within which a target can be detected, but causing no deficit in processing multiple objects per se.

Binocular Vision

Wednesday, May 18, 11:00 am - 12:45 pm
Talk Session, Talk Room 2
Moderator: Laurie Wilcox

62.21, *11:00 am* **A dynamic double pass technique for characterizing internal noise during binocular rivalry** Daniel Baker[1](daniel.baker@york.ac.uk), Bruno Richard[1]; [1]Department of Psychology, University of York

The perceptual alternations characteristic of binocular rivalry have a stochastic component that is a consequence of internal noise in the visual system. Yet little is known about the properties of this noise, as we lack methods to probe it directly. We used a standard binocular rivalry monitoring paradigm, in which observers viewed a pair of dichoptic orthogonal gratings (2c/deg, 50% contrast) for trials of one minute duration, and reported their percepts continuously using a mouse. We then injected dynamic noise into the stimulus by adding independent sequences of temporally bandpass-filtered noise to the contrasts of the two gratings. The peak temporal frequency (0.0625 to 1Hz) and standard deviation (1 to 16%) of the noise were combined factorially giving 25 conditions. Dominance durations and autocorrelation functions calculated across five repetitions per observer showed effects of both noise variance and frequency, indicating that alternations were driven by high amplitude external noise at all temporal scales. We then repeated the experiment using the same samples of noise for each condition, and calculated the consistency of the observer's responses across the two passes, in a novel dynamic variant of the 'double pass' method (Burgess & Colborne, 1988, J Opt Soc Am A, 5: 617-627). Consistency increased from baseline (50%) at noise standard deviations of 4% and above, providing an approximate estimate of the amplitude of internal noise. Consistency scores showed bandpass tuning, with the highest consistency (around 70%) occurring at 0.125Hz, falling off at higher and lower frequencies. Using anticorrelated noise across the eyes (rather than uncorrelated noise) produced a slight increase in consistency to around 75%, providing an upper bound on the range of values. Cross-correlation between the noise streams and observer responses indicated a response latency of around 0.5-1s. We discuss our results in the context of computational models of the rivalry process.

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62.22, *11:15 am* **Classifying Mixed Percepts During Binocular Rivalry in Younger and Older Adults** Amanda Beers[1](beersam@mcmaster.ca), Allison Sekuler[1], Patrick Bennett[1]; [1]1. Department of Psychology, Neuroscience & Behaviour, McMaster University

Several categories of mixed percepts can be seen during binocular rivalry, including the perception of both exclusive images overlapping, a mosaic comprising of pieces of each exclusive image, and a wave-like transition from one exclusive percept to the other (Yang et al., 1992). Recently, we demonstrated the overall proportion of mixed percepts decreases with aging (Beers et al., VSS 2013). However, it is unknown if all categories are affected by aging. To answer this question, we presented pairs of orthogonal, oblique sine wave gratings (diameter = 4.4; contrast level = 0.45) to fifteen younger (aged 18-26) and twenty older (aged 64-84) adults. On each trial, participants recorded each instance of a mixed percept category (overlapping, pieces, or wave-like) with a handheld button box. The total number of reported mixed percepts and the tallies for each category were analyzed. Older adults reported significantly fewer mixed percepts. Interestingly, the proportion of each category of mixed percept decreased at similar rates with aging. Eight participants from each age group returned for a second experiment in which stimulus size (diameter = 1.4 or 4.4) and contrast level (0.2 or 0.8), factors with well□known effects on characteristics of mixed percepts in younger adults, varied across trials. Overall both younger and older observers reported increased occurrences of mixed percepts at high compared to low contrast, primarily for the wave-like category. Younger adults reported fewer mixed percepts when viewing the smaller compared to the larger stimuli, consistent with previous results (Blake et al., 1992), a decrease primarily affected by the wave-like category. Older adults had significantly fewer instances of mixed percepts when viewing the small stimuli at low contrast, but the decrease was primarily affected by the pieces category. These classifications, and age-related differences, enhance our understanding of rivalry, as distinct neural mechanisms have been linked to specific categories.

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62.23, *11:30 am* **Face gender adaptation from random noise adaptors: A surprising prediction of Li and Atick's efficient binocular coding theory** Keith May[1](keith@keithmay.org), Li Zhaoping[1]; [1]Department of Computer Science, University College London

We present a novel face adaptation paradigm that follows from Li and Atick's (1994) theory of efficient binocular encoding. In this theory, the inputs to the two eyes are combined using separately adaptable binocular summation and differencing channels. We showed previously that, if a binocular test stimulus is designed so that the summation and differencing channels see opposite directions of motion or tilt, then the perceived direction of motion or tilt can be manipulated by selectively adapting one of the binocular channels, even if the adaptor contains no motion or orientation signal. Here we extend this to face gender adaptation. Our test stimuli were made from male and female facial composite images. In what follows, uppercase letters M and F are the male and female composite images, and lowercase letters are scalar multipliers that control image contrast. On half the trials, the summation and differencing channels receive male image aM and female image bF, respectively, made by inputs (aM+bF)/2 to one eye and (aM–bF)/2 to the other eye. On the other half of the trials, the summation and differencing channels receive female image aF and male image bM, respectively. The probability of perceiving the gender corresponding to the summation channel is influenced not only by the ratio a/b, but also by the contrast sensitivities of the summation and differencing channels. We manipulated channel sensitivities using adaptation stimuli that were low-pass filtered noise. In correlated adaptation, each eye received the same adaptation image, which selectively adapted the summation channel; in anticorrelated adaptation, the adaptor contrast was reversed between the eyes, selectively adapting the differencing channel. Despite being random noise, the adaptors influenced perceived gender: The probability of perceiving the gender corresponding to the summation channel increased after anticorrelated adaptation and decreased after correlated adaptation. The results support Li and Atick's theory.

Acknowledgement: This work was supported by a Grant to Li Zhaoping from the Gatsby Charitable Foundation.

62.24, *11:45 am* **Unreportable switches in bistable perception produce negligible fronto-parietal BOLD activity.** Tomas Knapen[1](t-knapen@gmail.com), Randolph Blake[2,3], Jan Brascamp[4]; [1]Cognitive Psychology, Vrije Universiteit Amsterdam, Amsterdam, the Netherlands, [2]Department of Psychology and Vanderbilt Vision Research Center, Vanderbilt University, Nashville, Tennessee, USA, [3]Department of Brain and Cognitive Sciences, Seoul National University, Seoul, Republic of Korea, [4]Department of Psychology, Michigan State University, East Lansing, Michigan, USA

To make a covert decision or initiate a motor act, executive systems in our brains fluidly reorganize to find a stable neural state corresponding to the decision or movement. It is unclear whether sensory systems can endogenously reorganize in similar ways, or whether executive input is needed for sensory systems to shift from one stable state to another. We developed a procedure in which perceptual state demonstrably switches between dominance of different input patterns, yet the switches themselves are so inconspicuous as to become unreportable, minimizing their executive consequences. We used binocular rivalry, a paradigm in which sensory ambiguity arises from the presentation of markedly different visual input to each eye. In our case, the two eyes were stimulated by perceptually similar, dynamic random dot kinematograms, in which we maintained the interocular conflict that causes binocular rivalry. Using this stimulus paradigm, observers perceive virtually no switches. But, by periodically presenting opposite motion directions to the two eyes, motion direction reports allow us to reconstruct the time course of eye-dominance. This implicit reconstruction shows that switches do occur when imperceptible, with time-courses comparable to fully visible binocular rivalry switches. We find fMRI and pupil evidence for engagement of executive functions on fully visible switches, but negligible activations if the perceptual switch is unreportable. Thus, the ability to rapidly and autonomously reorganize, commonly observed in higher-order cortical areas, is also present within sensory regions, and may be ubiquitous among neural networks across the human brain.

62.25, *12:00 pm* **Shifts in interocular balance resulting from short-term monocular deprivation in adult macaque visual cortex are not magno-dominated** Momotaz Begum[1](momo@tsolab.org), Daniel Tso[1]; [1]Depts Neurosurgery/Neuroscience/Ophthalmology, SUNY Upstate Medical University

Short-term monocular deprivation (STMD, patching one eye for 1-3 hours) disrupts interocular balance in adult humans, as measured psychophysically, and also in our present studies using anesthetized adult macaques, as measured with intrinsic signal optical imaging of the V1 ocular dominance columns. Surprisingly, in all these studies, the relative contribution of the patched eye was elevated after patch removal. V1 imaging studies using pattern deprivation rather than full occlusion STMD also yielded a similar rapid shift in interocular balance in which the contribution of the non-deprived eye showed a steady decrease during the deprivation of the other eye. Once the deprivation period ended, the non-deprived eye dramatically strengthened, despite the stimulus to this eye remaining constant during the entire experiment. Further experiments have shown that this STMD effect is not orientation-specific. To further probe the underlying mechanisms of the STMD effect, we tested "P-channel deprivation". As with the pattern deprivation studies, the stimuli were dichoptically viewed 4 degree gratings of various orientations. However during the 1-3hr deprivation period, one eye was presented with low contrast (8%), low spatial frequency (0.5c/deg) stimuli designed to only stimulate the magnocellular (M) pathways. The imaging data collected showed a shift in interocular balance to this "P-channel" STMD similar to that seen with pattern deprivation. These results suggest that the underlying neural mechanisms mediating STMD-induced shifts in interocular balance are binocular and unlikely to be magno-dominated (and also not orientation specific), but rather depends appreciably on parvo-channel activity. The weakened response for the non-deprived eye during the deprivation period is striking. It cannot be explained by adaptation or fatigue in the eye or cortex. These results suggests a dynamic mechanism for regulating interocular balance and gain that includes the neurons in V1.

62.26, *12:15 pm* **Binocular alignment in mice during stereoscopic discrimination of depth** Jason Samonds[1,2,3](samondjm@cnbc.cmu.edu), Veronica Choi[1,2,3], Nicholas Priebe[1,2,3]; [1]Department of Neuroscience, College of Natural Sciences, The University of Texas at Austin, [2]Center for Perceptual Systems, College of Liberal Arts, The University of Texas at Austin, [3]Center for Learning and Memory, College of Natural Sciences, The University of Texas at Austin

In order for animals with binocular vision to use retinal image disparity to infer depth, they must be able to maintain some alignment between the eyes. Primates and carnivores frequently make coordinated saccades, and when they fixate on an object, their eyes converge or diverge to align their retinal images at that point. Rodents do not have a fovea, saccade less frequently, and their eyes are typically directed at different objects. However, there is binocular disparity tuning in the primary visual cortex of mice. To study how mice might use this disparity tuning to discriminate depth, we examined binocular eye movements while mice were trained to discriminate between relative near and far surfaces rendered in dynamic random dot stereograms. We found that naïve head-fixed mice had very coordinated saccades between the eyes with mostly horizontal eye movements. As mice were able to significantly discriminate surfaces, they substantially reduced their eye movements. Overall, binocular eye movements were still positively correlated, but leading up to stimulus onset and during stimulation, binocular eye movements were negatively correlated. For both near and far surfaces, the mice would start converging their eyes seconds before stimulus onset and then diverge their eyes once making a decision about whether the surface was near or far. This is because the screen was in front of them, which is not their natural gaze location. We analyzed the average vergence angle with respect to their average gaze for correct and incorrect trials and found that when mice failed to detect near surfaces, their eyes did not converge. When mice failed to detect far surfaces, their eyes converged too much. This data demonstrate that mice do align their eyes and that their successful stereoscopic discrimination depends on proper binocular alignment.

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Wednesday AM

62.27, *12:30 pm* **Stereoscopic surface interpolation from illusory contours** Brittney Hartle[1](brit1317@yorku.ca), Richard Murray[1], Laurie Wilcox[1]; [1]Department of Psychology, and Centre for Vision Research, York University

Stereoscopic Kanizsa figures are an example of 3D illusory surface interpolation. In such stimuli, luminance-defined disparity signals exist only along the edges of the inducing elements, but observers reliably perceive a coherent surface in depth that extends across the central blank region. It is widely assumed that the 3D shape of the illusory surface is solely determined by the local disparity at the inducer edges, and then extrapolated to form a surface representation. Here we evaluate another alternative: that the illusory contours themselves also provide a disparity signal that contributes to the perceived 3D shape of the illusory surface. We measured stereoscopic depth magnitude percepts using a collection of Kanizsa figures with a wide range of inducer disparities. For comparison, we assessed similar figures with luminance-defined surfaces and a third condition where both illusory and luminance edges were present. Prior to testing, we measured individual diplopia thresholds for the inducer contours. Also, using a matching paradigm, we equated the perceived strength of the surfaces defined by luminance alone and by illusory contours. During testing, 3D Kanizsa figures were displayed in random order on a mirror stereoscope, and depth magnitude estimates were made using a touch sensitive sensor strip. We found that all 6 participants made depth magnitude estimates consistent with simple interpolation geometry, for all stimuli in the fused range; moreover, in this range of disparities, estimates for the illusory and luminance-defined stimuli were identical. At larger disparities, all observers reported increasing depth percepts with increasing disparity for the illusory figures. However, for half of our observers, depth estimates plateaued for the luminance-defined surfaces only. The correspondence between the suprathreshold depth percepts from luminance-defined and illusory Kanizsa surfaces, and the resilience of depth percepts from illusory figures suggests that in some cases binocular disparity can be extracted from illusory edges.

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Eye Movements: Applications

Wednesday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4001 **Precision and Accuracy of Oculo-motor Behavior in Patients with Central Vision Loss** Girish Kumar[1], Susana Chung[1,2]; [1]School of Optometry, UC Berkeley, [2]Vision Science Graduate Program, UC Berkeley

Patients who suffer from bilateral central vision loss (CVL) adopt a peripheral zone outside their damaged retina to view the world — the Preferred Retinal Locus (PRL). It is well known that the exact location of PRL can vary with tasks. We sought to determine whether or not the eye movement systems for fixation and voluntary saccade place visual targets within the same PRL. To answer this question, we used a Scanning Laser Ophthalmoscope to capture high-resolution videos of patients with CVL while they tracked an 0.8° square target that jittered either vertically or horizontally by an amplitude of 1.5° or 3°. The direction and amplitude of the target jumps were randomly interleaved. We used a cross-correlation algorithm to extract the patients' eye positions at a sampling rate of 540 Hz from the captured videos. Saccades were localized using a velocity criterion. The precise retinal location of the target following the cessation of catch-up saccades was determined. This post-saccadic target location was considered to be the goal of the saccadic system in our analysis. The spread of the target locations following saccades was quantified using the Bivariate Contour Ellipse Area (BCEA) and the mean target location was also calculated. These metrics were compared with similar values extracted from videos of the same patients fixating a 0.8° target. Across our patients, the BCEA for post-saccadic target locations ranged from 5.73 degree2 to 11.20 degree2 while the BCEA for target locations during fixation ranged from 3.87 degree2 to 8.26 degree2. The mean locations of the target post-saccade and fixation were separated by distances that ranged from 0.42° to 0.45°. These distances were not statistically significant, suggesting that these patients use the same PRL for fixation and saccadic eye movements; however, the precision for target placement is higher for the fixation system.

Acknowledgement: NIH R01-EY012810

63.4002 **Similar estimates of contrast sensitivity and acuity from psychophysics and automated analysis of optokinetic nystagmus** Steven Dakin[1,2](s.dakin@auckland.ac.nz), Phillip Turnbull[1]; [1]School of Optometry and Vision Science, Faculty of Medical & Health Sciences, The University of Auckland, [2]UCL Institute of Ophthalmology, University College London

Although the contrast sensitivity function (CSF) is a particularly useful way of characterising functional vision, its psychophysical measurement relies on observers being able to make reliable perceptual reports. This can be challenging e.g. when testing children. Here we describe a system for measuring the CSF without observer-report using an automated analysis of optokinetic nystagmus (OKN), an oscillatory eye movement made in response to moving stimuli (here, spatial-frequency - SF - band-pass noise). We show that predicting perceived direction using the proportion of eye movements that are consistent with OKN in the stimulus direction allows us to make an unbiased estimate of contrast sensitivity across SF. We next compare CSFs of 25 observers derived using either OKN or perceptual report. Both approaches yield near-identical CSFs that capture subtle inter-observer variations in acuity (R=0.80, p< 0.0001) and contrast sensitivity (R=0.80, p< 0.0001) amongst observers with ostensibly normal vision. A trial-by-trial analysis reveals that, even when observers' perceptual report is at chance, there is a very high correlation between our OKN-derived measure and observers' perceptual report. This indicates that OKN and self-report are likely tapping into a common neural mechanism providing further support for the proposal that OKN is a valid alternative to the current gold standard measures of CSF based on perceptual report. We discuss how our approach can be paired with an efficient psychophysical method to derive rapid automated measures of the CSF and other measures of functional vision.

Acknowledgement: New Zealand Association of Optometrists

63.4003 **Lost in Space: The Cost of Interruption During Search Through Volumetric Medical Images** Lauren Williams[1](lauren.h.williams@utah.edu), Trafton Drew[1]; [1]University of Utah

Computerized tomography, or CT, produces a series of cross sectional images that provide detailed three dimensional representations of the body's internal structures. According to Yu, et al., 2011, each 10 minute CT scan has a 59% chance of being interrupted by a phone call. The current study examines how these interruptions affect the accuracy and efficiency of volumetric visual search. In addition, eye-tracking data was recorded to determine how faithfully search is resumed after an interruption. Participants searched through 20 CT scans for artificial lung nodules. Lung nodules are identified as circles that pop in and out of view as the participant scrolls through the depth of the lung. Between 30 to 60 seconds after search onset, half of the trials were interrupted by a series of true or false math equations. The number of missed nodules did not differ between interruption and non-interruption trials. However, search duration was approximately 13% longer (22s) in interruption trials. Eye-tracking data was used to better understand the source of this time cost. Interruption trials were compared to non-interruption trials by randomly sampling eye position between 30 to 60 seconds into non-interruption trials. The first fixation after interruption was in a different quadrant of the lung in approximately 75% of trials, compared to a 35% change during equivalent time periods in non-interruption trials. These results suggest that interruption impairs memory for which regions of the lung have been examined. Previous evidence has suggested that memory for where we have searched is quite poor (Horowitz & Wolfe, 1998; Wolfe, Drew, Vo, 2014). The current study suggests that this limitation may be exacerbated by interruption. In future work, we will explore the factors that predict the costs of interruption with the eventual goal of helping mitigate these costs in diagnostic radiology.

Acknowledgement: DOD Grant W911NF-07-2-0055

63.4004 **Quantifying the costs of telephone interruptions during diagnostic radiology: A mobile eye-tracking study** Trafton Drew[1](trafton.drew@psych.utah.edu), Booth Aldred[2], Marta Heilbrun[2], Satoshi Minoshim[2]; [1]University of Utah Psychology Department, [2]University of Utah School of Medicine, Department of Radiology

Medical errors are one of the leading causes of death in America. In diagnostic radiology, an estimated 30% of errors are perceptual (Berlin, 2007), and thus preventable. The radiologists' task is made more difficult by increasingly common telephone interruptions. Correlational studies have shown that more interruptions correlate with more disagreements over diagnosis (Balint et al., 2014), but it is not clear what causes these effects. More generally, it is not clear what effects telephone interruptions have on diagnostic accuracy or duration of reading time on a case-by-case basis. Our study aimed to address this gap by asking advanced radiology fellows and attending physicians to read a heavy case-load of medical images in a reading room environment during off-hours while wearing mobile eye-tracking glasses. Each session included two phone calls, which interrupted the radiologists while they were reading complex volumetric cases with multiple views. A pre-corded message instructed the radiologist to find and examine a different patient's case. Telephone interruptions were counter-balanced across cases, allowing us to compare the cost of interruption on identical cases across radiologists. We found that cases that were interrupted were examined ~60s longer than uninterrupted cases. Surprisingly, each expert observer missed a retrospectively visible sternal fracture. Interestingly, the radiologists who were not interrupted during this case spent ~6x longer looking in the vicinity of the fracture than those who were interrupted. This includes one radiologist who, in the face of a distracting telephone interruption, neglected to examine any of the images where the sternum could be visualized. Together, this preliminary examination provides strong evidence that interruptions contribute substantially to the already challenging task that faces diagnostic radiologists. We hope that our eye-tracking data may provide means by which to mitigate some of these costs by enhancing the education of future radiology residents.

Acknowledgement: DOD W911NF-07-2-0055

63.4005 **A systematic search strategy in radiology: seeing more, missing less?** Ellen Kok[1](e.kok@maastrichtuniversity.nl), Halszka Jarodzka[2,3], Anique de Bruin[1], Hussain BinAmir[4], Simon Robben[5], Jeroen van Merriënboer[1]; [1]School of Health Professions Education, Maastricht University, [2]Welten Institute – Research Centre for Learning, Teaching and Technology, Open University of The Netherlands, [3]Humanties Laboratory, Lund University, [4]International Master in Medicine, Faculty of Health, Medicine and Life Sciences, Maastricht University, Maastricht, The Netherlands, [5]Department of Radiology, Maastricht University Medical Centre

Diagnosing chest radiographs is a complex task that is difficult to master for medical students. Many textbooks in radiology thus recommend a systematic search strategy for detecting abnormalities in a radiograph. This systematic search strategy entails that anatomic regions are always inspected in the same order over radiographs. This is expected to lead to a complete coverage of the radiograph, and by that it should lead to a lower number of missed abnormalities. There is, however, very little evidence for the recommendation to use a systematic search strategy. We therefore investigated the assumed relationship between systematic search, coverage and number of misses, as well as the effect of training on these variables. Seventy-five 2nd year medical students underwent training in a systematic, a full-coverage (no focus on systematicity) or a non-systematic search strategy. Eye tracking was used to investigate the amount of systematic search (using Levenshtein Distance) and average percentage coverage of images. A more systematic search (lower Levenshtein Distance) was correlated with increased coverage, $r = -.35$, $p < .01$. Neither Levenshtein distance nor coverage were related with number of misses (respectively, $r = .05$, $p = .73$ and $r = -.13$, $p = .31$). Participants who underwent systematic search training were more systematic than the two other groups, $K(2) = 16.58$, $p < .01$. Participants in the systematic search group, and the full-coverage group covered more of the image than the non-systematic search group, $K(2) = 7.42$, $p = .03$. Participants in the full-coverage group missed most of the abnormalities, while the systematic-viewing group and non-systematic viewing group did not differ significantly $F(2, 71) = 3.95$, $p = .02$. The eye tracking data show that the training influenced viewing behaviour as predicted. However, performance did not increase with increased coverage. The data question the effectiveness of teaching students to systematically search a radiograph.

63.4006 **Modelling the rapid adaptation of fixation durations during naturalistic scene viewing.** R Calen Walshe[1](calen.walshe@gmail.com), Antje Nuthmann[2]; [1]Center for Perceptual Systems, The University of Texas, [2]Department of Psychology, The University of Edinburgh

Understanding of visual scenes in natural viewing conditions takes place within very brief episodes known as fixations. Currently, it is a matter of open inquiry as to what factors influence the timing of these movements. One important question is how moment-to-moment changes in the visual quality of an image govern the length of a single fixation. In this work, we use a collection of gaze-contingent experiments to study the adaptation of fixation durations to changes in scene luminance. Then, we adopt a computational modelling approach to explain the empirical data. In the experiments, participants scan a scene to encode scene details for later recall. During the saccade that defines the interval between the 10th and 11th fixation the luminance of the entire scene is increased or decreased and the resulting change in fixation durations is observed. The results demonstrate that fixation durations increase in response to luminance decreases. However, luminance increases tend to result in smaller or no increase in fixation duration. This pattern of results suggests that fixation durations are directly controlled by stimulus content but in an asymmetric manner. We develop a model of eye-movement control that assumes two distinct influences on fixation timing. The first factor is related to the surprise induced by the sudden change in luminance which acts inhibitorily. The second factor is related to visual encoding which acts at longer time scales and may be inhibitory or facilitory. These principles are formalized into a computational model that is capable of generating simulated fixation duration distributions for these tasks. The model uses stochastic timing to simulate a) the timing of saccade initiation mechanisms and b) the timeline of saccade decision making processes. Through rapid, directly-controlled, changes in saccade preparation the model captures the pattern observed in the empirical distributions.

63.4007 **Can pupillometry dissociate fear and disgust? Trypophobia as a test case.** Meghan Hickey[1](meghanrose425@gmail.com), Vladislav Ayzenberg[1], Stella Lourenco[1]; [1]Psychology, College of Arts and Sciences, Emory University

Anxiety in response to objects with a cluster of holes has come to be known as trypophobia, and recent research suggests that such objects share low-level visual properties with evolutionarily threating stimuli, namely snakes and spiders (Cole & Wilkins, 2013). The current consensus is that, like snakes and spiders, the anxiety associated with holes is rooted in fear. However, self-reports from individuals with tryophobia suggest that anxiety may instead reflect a disgust reaction. Fear and disgust are difficult to disambiguate behaviorally because both involve an avoidance response (Granholm & Steinhauer, 2004). In the current study, we used pupillometry to test whether trypophobia is rooted in fear versus disgust. We predicted that if trypophobic stimuli elicited fear, then they should invoke a sympathetic response, which is associated with pupil dilation; alternatively, if trypophobic stimuli elicited disgust, then they should invoke a parasympathetic response, which is associated with pupil constriction (Granholm & Steinhauer, 2004). Thirty-six adult participants passively viewed a slideshow of trypophobic images (e.g., lotus seed pod, sponge), neutral images (e.g., cup), and threatening images (i.e., snakes and spiders). Presentation order was randomized and each trial consisted of a neutral gray screen (6 s) followed by an image (6 s). All images were grayscaled and equated for luminance. Analyses revealed that trypophobic images elicited significant pupil constriction relative to threatening and neutral images ($ps < 0.001$), suggesting a disgust, not fear, response. However, because of the fine-grained spatial detail of trypophobic stimuli, an alternative possibility is that constriction resulted from pupil foveation. We are currently testing this possibility by comparing trypophobic and non-trypophobic images with comparable spatial properties.

63.4008 **Do eye movements referenced to an extra-foveal retinal location in the absence of a functioning fovea?** Susana Chung[1,2](s.chung@berkeley.edu), Girish Kumar[1]; [1]School of Optometry, UC Berkeley, [2]Vision Science Graduate Program, UC Berkeley

People with bilateral macular disease usually adopt a retinal location near the edge of their retinal lesioned area for seeing — the preferred retinal locus (PRL). Is the PRL the new reference locus for oculomotor movements in response to the loss of a functioning fovea? Here, we examined whether microsaccades made during fixation, or saccades made voluntarily in response to a moving target, bring an object of interest toward the fovea (absence of oculomotor re-referencing) or the PRL (evidence of oculomotor re-referencing). Images of the retina showing the target retinal locations were recorded using a high-resolution scanning laser ophthalmoscope while participants with long-standing bilateral macular disease either fixated at a target, or made saccades to follow a target that jumped between different positions. Eye positions were extracted from the recordings using a brute-force cross-correlation algorithm at a sampling rate of 540 Hz. Retinal locations corresponding to the target location before and after each saccade were determined. The vector error of the landing position of each saccade was calculated with respect to the fovea and the PRL. For fixation trials, vector errors of microsaccades were much smaller when calculated with respect to the PRL than the fovea, suggesting that microsaccades during fixation were directed toward the PRL, not the fovea, evidence of oculomotor re-referencing. In contrast, vector errors of saccades made during voluntary saccade trials were not different when analyzed with respect to the fovea or the PRL, implying no clear single reference location for voluntary saccadic eye movements. Our findings of the different extent to which saccades were directed toward the PRL for fixation vs. voluntary-saccade tasks suggest that the neural circuits or control of different types of eye movements are associated with different degrees of plasticity, elucidating important properties of the neural control of eye movements in general.

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63.4009 **Visual Attention and Eye Movement Deficits in Patients with Traumatic Brain Injury** Tori Espensen-Sturges[1](espe0107@umn.edu), Timothy Hendrickson[2], Andrea Grant[3], Scott Sponheim[1,3,4], Cheryl Olman[1]; [1]Department of Psychology, University of Minnesota, [2]Department of Psychiatry, University of Minnesota, [3]Department of Neuroscience, University of Minnesota, [4]Veterans Affairs Medical Center, Minneapolis, MN

About two-thirds of people suffering from mild to moderate traumatic brain injury (mTBI) suffer from some sort of visual disturbance (Goodrich et al., 2013). These patients suffer can suffer from reduced visual acuity and visual field, as well as deficits in visual attention and occulomotor skills. The present study is investigating whether visual attention and oculomotor deficits might be explained by cortical damage from mTBI. Veterans previously diagnosed with traumatic brain injury and combat controls are being recruited for a battery of behavioral tasks aimed at quantifying spatial attention allocation, eye movement accuracy, and motion perception ability. In addition, the fMRI arm of the study targets the frontal eye fields (FEF) and intraparietal sulcus (IPS), cortical regions involved in planning eye movements as well as prioritizing visual attention (Jerde et al, 2012). Because mTBI also impacts integrity of white matter (WM) tracts (Davenport et al., 2012), diffusion weighted imaging is also being used to assess the integrity of WM adjacent to frontal and parietal regions of interest. Of the 14 mTBI patients who have participated in behavioral tests at the time of abstract submission, 9 demonstrated convergence insufficiency (57%), as compared

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with 2 of 9 (22%) of combat controls. Additionally, mTBI patients with demonstrably normal acuity and convergence performance report double vision during reading and other visual tasks in cluttered environments. The goal of the study is to use fMRI and DTI to identify biomarkers for these oculomotor deficits that arise during visual processing of complex scenes.

63.4010 **In search of the visual and oculomotor factors that determine the location of a preferred retinal locus** Helga Mazyar[1](mazyar@usc.edu), Bosco Tjan[1,2]; [1]Neuroscience Gradate Program, University of Southern California, Los Angeles, [2]Department of Psychology, University of Southern California, Los Angeles

Saccades bring objects of interest to the fovea. Losing foveal vision leads to the adoption of a preferred retinal locus (PRL) for fixations, sometimes with saccades re-referenced to the PRL. The retinal location of a PRL varies greatly across individuals. It is not known what visual and/or oculomotor factors may determine a PRL's location. Measuring these factors before the formation of a PRL had not been feasible. We developed a method that constrains PRL formation to a one-dimensional contour, in normally sighted participants. The method allows us to systematically measure visual and oculomotor characteristics along the contour before and after PRL formation. We assessed form vision (visual acuity, crowded visual acuity, position uncertainty) and oculomotor performance (peripherally guided fixation stability and saccade accuracy) of normally sighted participants at 8 evenly spaced locations on an imaginary circle, 6° radius and centered at the fovea. We used the Contact Task (Mazyar & Tjan, 2015 VSS) to induce a PRL. Participants had to move an opaque and gaze-contingent disc, 6° in radius and centered at the fovea, to make contact with a small target, which appeared at a random screen location in each trial. The participant had to establish contact between the edge of the disc and the target and maintain it for 500 ms before the target was dismissed and a new trial began. A preferred contact point (the induced PRL) naturally emerged and stabilized within 1000-2000 trials in all 3 participants, replicating our previous findings (7 out of 8 participants). The formed PRLs were in the lower (2 participants) or the left visual field. The rapid and stable formation of PRL suggests that underlying factors governing PRL formation should be crisp. However, none of our measured visual and oculomotor characteristics could predict PRL location. A larger study is needed.

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63.4011 **Transfer of Peripheral Fixation Training Across Retinal Eccentricities** Dylan Rose[1](rose.dy@husky.neu.edu), Peter Bex[1]; [1]Psychology, Northeastern University

We demonstrated recently that feedback-based peripheral oculomotor training improved fixation stability equally along cardinal retinal axes and that learning transferred to untrained locations (Rose & Bex, VSS 2014). This suggests that meridional asymmetries in eccentric perceptual function may not analogously impact oculomotor control. These findings have positive implications for the trainability of Preferred Retinal Loci (PRLs) during visual rehabilitation. However, meridional effects are generally of less concern than those associated with retinal eccentricity. We therefore examined oculomotor training and transfer of learning across changes in retinal eccentricity at a fixed orientation relative to the fovea. Eight individuals with normal or corrected-to-normal vision completed two, half-hour blocks of eccentric viewing training, separated by a week. Their task was to guide an eccentrically-positioned, gaze-contingent ring over a stable fixation target. The ring's diameter decreased when the subject maintained the ring on-target and increased when it fell off-target. The eccentricity of the gaze-contingent ring was 6.4 or 11.2 degrees, and was changed betwen blocks in counterbalanced order across subjects. A two degree diameter gaze-contingent simulated central scotoma prevented foveation. Performance was measured in degrees of error between the ring's center and the target's center, and was analyzed through fitted hierarchical linear models. As in the previous study, there was a significant, positive main effect of training and no main or interaction effects of eccentricity or eccentricity order. This finding, in conjunction with our previous work, suggests the exciting possibility that PRLs may be trained and subsequently relocated to new retinal locations selected exclusively to maximize perceptual functioning, without simultaneously impairing oculomotor control.

63.4012 **A comparison of eye-movement patterns between experienced observers and novices in detecting harmful intention from surveillance video** Joseph Burling[1](jmburling@ucla.edu), Hongjing Lu[1], Greta Todorova[2], Frank Pollick[2]; [1]Psychology, University of California, Los Angeles, [2]Psychology, University of Glasgow

Understanding the intentions of others by viewing their actions in a complex visual scene is a challenging task. Does experience change looking behavior in that gaze to specific action cues creates a fixation "signature" unique to experienced observers? To address this question we analyzed eye movements between experienced surveillance (CCTV) operators and novices when observing social interactions from CCTV footage. 11 experienced operators and 10 novices observed 36 unique CCTV clips, while obtaining point-of-gaze coordinates from an eye tracker. Each clip was 16 seconds in duration, and classified based on one of four contexts. 'Fight' and 'Confront' clips displayed aggressive behavior, except that fighting actually occurred for 'Fight' clips after the end of the clip (not seen by the participants). 'Play' clips showed playful interactions between people with no aggression, while 'Nothing' clips showed typical everyday behavior with no aggression. We used a sequence matching algorithm to compare eye-movements (scan paths) between individuals examining the same video. We split sequences into segments (first, middle, and last) to analyze how viewing behavior changes with the accumulation of visual input over time. We found that on average, experienced operators yielded higher fixation similarity scores suggesting in-group consistency among experienced observers, with the consistency varying by context and time segment. For both the 'Confront' and 'Fight' contexts, differences in gaze patterns between experienced observers and novices were largest for the middle segment, whereas for the 'Play' context, the largest difference was at the end. The 'Nothing' context yielded higher scores for experts but no time differences. These results suggest that expert CCTV operators predict actions similarly by attending to the relevant events within a scene, and for critical events such as aggressive behaviors, important cues (markers that result in signature looking patterns) are attended well before the onset of the disruptive action.

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63.4013 **Gaze-entropy as a task load index for safety-critical operators: military pilots and surgeons.** Leandro Di Stasi[1,2,3](distasi@ugr.es), Carolina Diaz-Piedra[2,3], Hector Rieiro[2,4], Juan Ruiz-Rabelo[5], David Cardenas[6], Alberto Cherino[7], Gonzalo Olivares[8], Luis Fuentes[9], Andres Catena[2]; [1]Joint Centre University of Granada - Spanish Army Training and Doctrine Command, Spain, [2]Mind, Brain, and Behavior Research Center, University of Granada, Granada, Spain, [3]College of Nursing and Health Innovation, Arizona State University, Phoenix, AZ, USA, [4]Department of Signal Theory and Communications, University of Vigo, Vigo, Spain, [5]Department of Physical Education and Sport, University of Granada, Granada, Spain, [6]Spanish Army Airmobile Force, 1st Attack Helicopter Battalion (BHELA I), Almagro, Spain, [7]Andalusian Public Foundation for Progress and Health, Ministry of Equality, Health and Social Policy of the Regional Government of Andalusia, Granada, Spain, [8]University Hospital Reina Sofia, Cordoba, Spain, [9]Department of Basic Psychology and Methodology, University of Murcia, Murcia, Spain

Background: Task (over)load imposed on operators who work at safety-critical environments is a main contributing factor to the occurrence of catastrophic errors. Laboratory research has shown that gaze metrics represent a valid tool to asses operator task load. Thus, gaze metrics have the potential to improve operator and system safety by providing accurate and objective measurements of task load variations and subsequent operational recommendations. However, in many of the diverse safety-critical environments where this information could be of use, such as aviation or surgical domains, the direct relationship between gaze metrics and task load has not been investigated yet. Here, we studied the effects of task complexity on the gaze metrics of combat helicopter pilots and surgical trainees. Methods: We recorded the eye movements of the entire attack helicopter battalion of the Spanish Army (n=13), and of surgical trainees from the Andalusian healthcare system (n=25), using a mobile eye-tracker system (Tobii Glasses 2.0), while performing several high-fidelity virtual simulation exercises of different complexity levels. We also measured performance and collected subjective ratings of complexity. Results: Among helicopter pilots, gaze entropy decreased with increased task complexity: visual exploration pattern became more stereotyped (i.e. less random) during the more complex tasks (i.e. flight emergencies). Among surgeon trainees, we found the opposite trend. In both cases, performance and perceived task complexity differed as expected. Conclusions: Our results show, for the first time, that gaze metrics are a valid index of task load in safety-critical environments. Task features and visual display solutions might explain different trends in pilots and surgeons. These findings have the potential to improve flight and patient safety by providing accurate measurements of operator task (over)load. These findings might also lead to future indices for the assessment of operators' learning curves without the need for time-consuming expert evaluation.

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63.4014 **Recognizing harmful intent from surveillance video viewed through the eye-movements of novice and experienced observers**
Frank Pollick[1](frank@psy.gla.ac.uk), Greta Todorova[1], Steven Thurman[2], Joseph Burling[2], Hongjing Lu[2]; [1]School of Psychology, University of Glasgow, [2]Psychology Department, University of California, Los Angeles

To discern intention, based on the observation of complex human behaviour, typically requires eye-movements that actively explore the visual context. We examined whether the gaze patterns of novice and experienced observers would differentially inform intention judgments of naïve viewers. To achieve this we first obtained real-life surveillance (CCTV) videos and organised them into 24 videos of 16-second duration in four categories ('fight', 'confront', 'nothing', 'play'). 'Fight' and 'confront' included aggressive behaviour, but only 'fight' videos resulted in a violent incident (after the video ended). 'Play' videos showed playful behaviour and the 'nothing' videos showed a variety of everyday activity that did not include aggressive behavior. We then obtained eye-movement data from novice and experienced CCTV operators who viewed these videos with the goal of judging hostile intent. Next, a high resolution foveal window with a blurred periphery was overlaid on each video according to the gaze coordinates of a novice or experienced operator. Twenty-four of these videos were created and shown to naïve participants, with half from each category being processed through an operator's eye-movements and half through a novice's eye-movements. Participants were instructed to follow the foveated area and try to ignore the blurred surrounding. For each trial they made a Yes/No judgement of whether a violent incident occurred after the video ended, and rated their confidence on a 7-point scale. Signal detection analysis was carried out on the Yes/No responses with a 'yes' on the 'fight' videos coded as a hit, and on any other video as a false alarm. Results showed no significant differences in sensitivity or bias. Results of confidence judgments revealed a trend of increased confidence when following novices' eye-movements. These preliminary results suggest that naïve participants were not able to extract more information from the operator scanpaths but subjectively found the experience different.

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Eye Movements: Pursuit

Wednesday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4015 **Saccade and pursuit interactions for following moving targets**
Doris Braun[1](doris.braun@psychol.uni-giessen.de), Karl Gegenfurtner[1]; [1]Giessen University, Germany

Visual tracking movements consist of two very different components: saccades and smooth pursuit. Under natural conditions, we frequently initiate a saccade to a peripheral object when it begins to move. This situation, where the direction of the saccade and subsequent pursuit are different, has not yet been systematically investigated under laboratory conditions. A single Gaussian blob appeared 5 deg eccentrically relative to a central fixation spot, either at the same vertical position or diagonally at an angle of 30 deg upward or downward. After the observer fixated the target for 500 ms, it made a step back towards the center of the display, and then moved at 20 deg/s in the direction opposite of the initial position, randomly in one of three directions, either horizontal or diagonal at 30 deg degrees upward or downward. Eye position was measured with an EyeLink 1000 system. Observers typically made initial saccades towards the center and then followed the target by smooth pursuit. The exact saccade landing position depended heavily on the subsequent pursuit direction. Saccades were displaced in the direction of the pursuit target. This effect increased with saccadic latency. We found three benefits when the direction of initial saccades and subsequent pursuit were identical: post saccadic position errors between the saccadic landing position and the moving target were smallest, post saccadic pursuit directional precision was highest and post saccadic pursuit speed after initial saccades were higher by 1 to 3 deg/s, This effect was strongest for the purely horizontal trials. We conclude that saccades and pursuit interact dynamically to optimize the following of sudden peripheral motion onsets.

Acknowledgement: DFG SFB TRR 135

63.4016 **Smooth pursuit and gaze stabilization: an integrated computational model**
Dinesh Pai[1,2,3](pai@cs.ubc.ca); [1]Department of Computer Science, University of British Columbia, [2]Center for Brain Health, University of British Columbia, [3]Institute for Applied Mathematics, University of British Columbia

INTRODUCTION: Smooth pursuit eye movements are slow rotations that allow the eye to track a moving visual stimulus. In contrast, the vestibulo-ocular reflex (VOR) is a low-latency reflex in which the eye counter-rotates to compensate for head movements and stabilizes gaze relative to spatial targets. These movements are generally believed to have little to do with each other, and are usually studied independently. Here, we present an integrated computational model that can generate both VOR and pursuit, depending on the stimulus. METHODS: The model is organized into several feedback loops, with each component representing a neural structure known to participate in eye movements. First, we show that vestibular input may be used to convert a desired 3D gaze velocity signal into the velocity of the eye relative to the head. We propose that this conversion occurs in the floccular target neurons or eye-head neurons in the brain stem. Second, we model the motor neuron pool and the cerebellum as an adaptive controller that learns to control eye velocity relative to the head, with efference copy from PMT cell groups and a teaching signal from retinal slip. Third, pursuit is achieved by providing a descending desired gaze velocity to the above structures. The motion of a target in retinal coordinates (estimated in areas MT and MSTl) may be converted to desired gaze velocity (possibly in FEF or the rostral pole of the superior colliculus). RESULTS: The implemented model produces VOR movements when only the head is moved, and pursuit eye movements when a designated visual target is moved. We have also implemented this model with a robotic eye [Lesmana, et al. 2014]. CONCLUSION: Our findings suggest that smooth pursuit is an integrated part of the gaze stabilization system and utilizes the phylogenetically older mechanisms related to VOR.

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63.4017 **To fixate or pursue? Manipulating eye movements to combat the size-speed illusion**
Helen Clark[1](hclark@waikato.ac.nz), John Perrone[1]; [1]The University of Waikato, New Zealand

The size-speed illusion is where longer objects moving in depth are judged to be moving slower than shorter objects travelling at the same speed. This may have consequences in the judgement of approaching vehicles and could account for vehicle collisions at level-crossings. Recently it has been shown that the size-speed illusion may be related to the movement of our eyes. Clark, Perrone, Isler and Charlton (AA&P, 2016) found that when observers tracked trains and cars in a simulated environment, their eye movement behaviour was different when they judged the speed of the longer train compared to the smaller car. Eye fixations were localised around the visual centroid of the train and consequently were further from the front of the train compared to the car. It has also been found that the magnitude of the size-speed illusion can be reduced by manipulating eye movements (both smooth pursuit and fixations), with the use of tracking dots placed at strategic locations on the vehicles or by placing a reference marker in the surrounding environment (Clark et al., 2016). Using this information, three level-crossing collision preventative measures were investigated in an applied setting designed to manipulate observer eye movements: (1) Alternating flashing lights placed on the front of trains. (2) Marker poles beside the railway line and (3) A mesh 'windbreaker' screen along part of the railway line. Results show that the flashing light intervention had the greatest effect; observers consistently judged a train with flashing lights to be moving faster than a regular train moving at the same speed. The poles had a smaller effect, while there was no discernable effect in speed discrimination between the mesh fence condition and a regular train. Our results show that interventions designed to influence smooth pursuit are the most effective in the vehicle speed discrimination task.

63.4018 Discriminating curvature of motion trajectories during fixation and smooth pursuit Nicholas Ross[1](nick.ross@psychol.uni-giessen.de), Alexander Schütz[2], Doris Braun[1], Karl Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen, [2]Fachbereich Psychologie, Philipps-Universität Marburg

Motion perception can be distorted (Filehne, 1922) or enhanced (Spering, Schütz, Braun, & Gegenfurtner, 2011) by smooth pursuit. Here we investigated the role of smooth pursuit in discriminating curvature of motion trajectories. Subjects viewed a white 0.5 deg diameter Gaussian blob on a black background in total darkness as it moved along an arc of constant curvature for 1s (standard). Then after a 1.5s delay, a second motion trajectory (comparison) was viewed for 1s after which subjects used a button press to report which path appeared "flatter". No feedback was given. Viewing condition was blocked. Subjects either fixated a point at the center of the motion trajectory or were instructed to smoothly follow the target as it moved across the screen. In order to prevent the use of the fixation point as a spatial reference, the comparison trajectory was randomly rotated away from the standard by +/- 0, 5,20, or 90 degrees. Psychophysical discrimination thresholds were lower during pursuit (M = 1.09,SD = 0.27o) compared to fixation (M = 1.33,SD = 0.44o), where M and SDs represent differences in radius of curvature between standard and comparison. We evaluated oculomotor curvature discrimination by calculating oculometric functions, with curvature judgments derived from the average signed distance between each de-saccaded unfiltered position sample in a particular interval and a line connecting the first and last points of the interval. Larger distances indicated more curvature. The results indicated that a window of 300 ms beginning at the start of steady state was required to successfully decode curvature from eye positions. Even then, pursuit thresholds never reached psychophysical thresholds and on average were larger by a factor of 3. These results indicate that smooth pursuit may be useful in discriminating curvature in motion, even though the pursuit itself indicates little curvature.

Acknowledgement: DFG SFB/TRR 135

63.4019 Do we foveate targets during smooth pursuit? Natela Shanidze[1](natela@ski.org), Stephen Heinen[1], Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Saccades have been shown to land at the center of mass of the target (He & Kowler 1991). Here, we examined if eye position is similarly centered on a target during typical smooth pursuit. Pursuit is considered a foveating behavior, even though it is driven by velocity and not eye position (Rashbass 1961), and has been demonstrated in the periphery (Winterson and Steinman, 1978). We recruited 8 untrained participants (age: 25-35, 3 males). Targets were displayed in a scanning laser ophthalmoscope (SLO) and moved in a modified step-ramp paradigm, stepping 6° from the center and moving through a 12° trajectory, at 6°/sec in 8 directions (0-315° in 45° increments). Targets were ring-shaped and either small (0.6°) or large (1.7°). Monocular fixation stability of each participant was measured to determine the 68% bivariate contour ellipse area (BCEA). Eye and target positions were compared directly on each frame during the longest period of continuous pursuit. Across participants, the target center rarely fell within the BCEA for either small (0.24±0.10) or large (0.16±0.12) targets. However, instances where any part of the target fell within the BCEA were substantially more common (small: 0.69±0.13; large: 0.79±0.22). In some cases, pursuit loci were up to 3-4° from BCEA boundary, arguing against a centering strategy. We also examined whether displacement around the center was related to the quality of pursuit gain. There was no relationship between gain and target placement. Furthermore, the non-centering trend persisted even for trials with near-perfect gains (within 1±0.15), arguing against retinal slip. Our results show that eye position is not centered on the target in pursuit. Unlike in Kowler & Blaser (1994), the distribution of eye position around the target cannot be explained by a bias from target center. This outcome raises the question of whether pursuit is indeed a foveating behavior.

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63.4020 Another reason for following an object with one's eyes if one intends to intercept it Cristina de la Malla[1](c.delamalla@gmail.com), Jeroen Smeets[1], Eli Brenner[1]; [1]Department of Human Movements Sciences, Vrije Universiteit Amsterdam

The most obvious reason for looking at an object that one is trying to intercept is that doing so maximizes the spatial resolution of judgments about the object's position. In order to intercept the object one needs to know its future position, for which an estimate of the target's motion is needed. Biases in motion perception will therefore lead to systematic errors. As motion perception is based on a combination of retinal and extra-retinal signals, eye movements may influence such biases. Here, we examine whether following the object with one's eyes makes interception less susceptible to biases in motion perception. We asked participants to tap on disks that moved across a large screen. Disks moved to the right at various constant velocities. There were solid disks and patterned ones. We biased motion perception by moving the pattern within the patterned disks. The pattern's motion either corresponded with a projection of how the pattern would move if the disks were rolling balls (so that the pattern within the disk moved up to twice as fast as the disk itself), or to how it would move if the disks were balls with backspin (so that the pattern moved more slowly than the disk). On each trial, the instruction was either to follow the disk with one's eyes or to fixate the position at which one will try to hit it. The different instructions, velocities and kinds of targets were randomly interleaved. When subjects fixated the interception point, moving the pattern within the disk caused large systematic errors. These errors almost disappeared when participants followed the disks with their eyes. Thus, following moving objects with one's eyes has the additional advantage of making one less sensitive to the imperfections of motion perception.

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63.4021 Predictive movements of the hands and eyes to a target that disappears briefly when moving in depth. Gabriel Diaz[1](Gabriel.Diaz@rit.edu), Kamran Binaee[1], Flip Phillips[1,2]; [1]Chester F. Carlson Center for Imaging Science, Rochester Institute of Technology, [2]Department of Psychology and Neuroscience, Skidmore College

When attempting to intercept a naturalistic target in flight (e.g. a thrown ball), humans initiate movements of the eyes and hand that are predictive of its future trajectory. However, it is unclear if the hands and eyes rely upon common or distinct predictive strategies. Studies suggest that online control strategies offer a sufficient account of hand positioning when the target moves in depth. In contrast, investigations of the oculomotor tracking of a target moving across a 2D plane suggest that visual pursuit utilizes a short-duration internal model of the target's future trajectory. Correlated error in the predictive movements would provide evidence for a common predictive strategy, yet few studies have investigated this for a target moving in depth. To investigate, we present a study in which subjects immersed in a virtual environment intercepted a target that disappeared during flight. Both the initial location and the location where it passed by the subject were randomized between trials. The duration of disappearance is a constant value of 500 ms on every trial. Three possible values of pre-disappearance duration (600, 800, and 1000 ms), and post-disappearance duration (200, 300, and 400ms) were randomly selected on a trial-by-trial basis. Because the target reappears very shortly before its arrival, one can improve the quality of post-disappearance visual feedback by predictively directing gaze towards the expected location of target reappearance. Similarly, placing the hand at a predicted passing location prior to reappearance can reduce the magnitude of movement required after reappearance. Analyses focus upon the error of these predictive movements and demonstrate a tight relationship between strategies for guidance of the eyes and hand.

63.4022 Maintaining smooth pursuit after target disappearance with eye-induced reverse-phi motion Arthur Portron[1](arthur.portron@ens.fr), Jean Lorenceau[1]; [1]Laboratoire des Systèmes Perceptifs (CNRS, UMR 8248), Département d'Etude Cognitive, Ecole Normale Supérieure-PSL*, Paris, France

The gain and speed of smooth pursuit eye movements quickly drop whenever a moving tracked target disappears behind an occluder [1] [2]. In 3 experiments, we test whether, and to what extent, pursuit maintenance after target disappearance depends on occluder's characteristics. In all experiments, a target moving for 900 (or 450) ms at 13.3 (or 26.6) °/s., disappears behind an occluder for 700 (350 or 1350) ms. Participants are asked to maintain their pursuit eye movements, recorded with an Eye-Link 1000, as long as possible. Experiment 1 uses 4 occluders: visible/invisible uniform occluders, random texture of disks, static/flickering (darker of brighter than background, 10 Hz). Experiment 2 uses varying flickering frequencies of texture of disks (6-10-20-40-60 Hz). Experiment 3, uses flickering textures of disks with different contrast reversals (LIGHT/light, DARK/dark, light/dark, relative to background (31.49 cd/m²). The results of Experiment 1 show that pursuit after target disappearance is maintained for longer durations (~700 ms) for a flickering texture as compared to the other occluders. Experiment 2, reveals a band pass effect of the frequency of the flickering texture, with longer pursuit maintenance for 20 and 40 Hz, relative to other flickering frequencies (6 and 60 Hz). The results of Experiment 3 show that pursuit maintenance is better with a balanced -dark/light- flickering contrast, than for the other contrasts conditions. Altogether, the results suggest that a flickering occluding texture with balanced contrast elicits eye-induced reverse-phi motion responses in V1 [3] and MT neurons [4] that contribute on-line to the maintenance of smooth pursuit for a long duration, in the absence of any explicitly moving target. The implications of these findings for modeling of smooth pursuit will be discussed.

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63.4023 **Local recalibration to background motion during smooth pursuit eye movements** David Souto[1,2](ds572@le.ac.uk), Karl Gegenfurtner[2], Alexander Schütz[3]; [1]Department of Neuroscience, Psychology and Behaviour, University of Leicester, United Kingdom, [2]Department of Psychology, Justus-Liebig Universität Giessen, Germany, [3]Department of Psychology, Philipps-Universität Marburg, Germany

How does the visual system maintain an accurate perception of motion in the world during smooth pursuit eye movements? Previous research suggests there is a recalibration mechanism that shifts the point of subjective stationarity (PSS) to correspond to the predominant background motion experienced during previous eye movement episodes. This recalibration mechanism could act globally and shift estimates across the visual field. We examined this possibility by repeatedly showing the same background motion relative to the pursuit direction in one location (upper or lower visual field, 5 deg eccentricity) and measuring the PSS in the same or opposite visual field. During recalibration trials, observers pursued a dot moving horizontally (7.6 deg/sec) and background motion was shown for 200 ms through a horizontal aperture (30 x 4 deg). On different sessions the background moved at 5 deg/sec either in the direction of pursuit or against it, resulting in retinal velocities of -2.6 and -12.6 deg/sec respectively. On test trials, 30% of the total, we mapped the PSS by varying background velocity and asking whether background motion was perceived leftward or rightward in the world. We found recalibration: a shift in the PSS in the direction of background motion relative to a control in which only test trials were shown. This effect was specific to the location that was stimulated during recalibration trials, therefore ruling out a global recalibration mechanism. Further experiments are underway to determine the spatial tuning of the recalibration, with the aim of comparing to the spatial tuning of the cells in medial superior temporal (MST) cortex that encode motion in the world during pursuit eye movements.

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63.4024 **Pursuing a small spot engages a different mechanism than pursuing a feature on a large object** Scott Watamaniuk[1,2](scott.watamaniuk@wright.edu), Elena Potapchuk[2], Stephen Heinen[2]; [1]Dept of Psychology, Wright State University, [2]The Smith-Kettlewell Eye Research Institute

Our previous work showed that pursuing large objects is less saccadic and less attentive than pursuing a small spot (Heinen et al., 2011; Jin et al., 2014). We proposed that a motion mechanism is predominantly used to pursue large objects while a foveal, position mechanism is engaged to pursue spots. But which mechanism is recruited when observers view small features on a larger pursuit object? To address this question, observers pursued, in separate blocks, either a single spot (0.2 deg) or a spot centered on a larger circular array (6° diameter) of eight 0.2 deg "feature" spots. All stimuli translated across the screen at 7 deg/s. Well after pursuit reached steady state (900-1400 ms), a randomly selected feature spot on the array brightened and enlarged, and observers made a saccade to it and pursued it for the remainder of the trial. In single-spot blocks, the initial spot target disappeared as the saccade target appeared at one of the eight possible feature spot locations. We found an almost complete cessation of catch-up saccades for an extended period preceding the targeting saccade. This saccade quieting period began earlier, and lasted longer, during pursuit of the large object. Saccade cessation was accompanied by a simultaneous reduction in eye velocity. The decrease was greater during spot pursuit, indicating that preparing for a gaze shift hampered pursuit of the spot more than it hampered pursuit of the large object. Therefore, pursuit of a small spot is different from pursuit of a small feature on a large object. These results, combined with our previous work, suggest that engaging a position mechanism to pursue conflicts with preparing a saccade to another target or feature. The brain solves this problem during pursuit of larger objects by relying on the motion system to pursue.

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63.4025 **Catch-up saccades during pursuit correct position error with the help of attention** Stephen Heinen[1](heinen@ski.org), Elena Potapchuk[1], Scott Watamaniuk[1,2]; [1]Smith-Kettlewell Eye Research Institute, San Francisco, CA, [2]Wright State University, Dayton, OH

Previously, we showed that more catch-up saccades occur when a pursuit stimulus has a central target than when it does not, and attending to the central target further increases saccade frequency (Heinen et al., VSS 2014; 2015). But why does this happen? Since retinal position and velocity errors contribute to catch-up saccade generation (deBrouwer et al., 2002), we sought to understand whether these factors are affected by the absence of a central pursuit target or varying attention demands. We first investigated the influence of a central target. Stimuli were either a single spot, four peripheral dots arranged in a virtual diamond, or a 5-dot composite of the two. Critically, all stimuli are symmetrical, and would create identical magnitude position and velocity errors on the retina if they were pursued equally well. Indeed, we found that position and velocity error were the same across all stimuli. However, position-error was a more potent saccade trigger for stimuli with foveal targets than those without. In the second experiment, we directed attention to and away from the fovea using a detection task in which either the central target or a peripheral one briefly dimmed. Again, position and velocity error were the same for all stimuli, and now, attention to the central target enhanced the influence of position error on saccade generation. Importantly, it was the relative contribution of position error to catch-up saccade generation that was greater for stimuli with a central target, and greater still when that target was attended. Conversely, removing the central target, or taking attention away from it, produced saccades driven primarily by velocity error. The results suggest that attention to a foveal target amplifies the position error signal during pursuit, and the system generates more catch-up saccades to correct this error.

63.4026 **Asymmetry in saccadic latency during smooth pursuit: A signature of visual spatial attention?** Madhumitha Mahadevan[1](M-Mahadevan@central.uh.edu), Harold Bedell[1], Scott Stevenson[1]; [1]University of Houston, College of Optometry

Previous studies reported faster saccadic reaction times (SRTs) for targets presented in the same compared to the opposite direction of pursuit, suggesting that the locus of visual spatial attention might be ahead of the pursuit target. We revisited these findings to investigate if task instruction or saccadic amplitude influenced the difference in SRTs between forward and backward saccades during ongoing pursuit. The pursuit target was a single letter from the set, CDHKNORSVZE, which traversed the screen horizontally in sinusoidal motion with a peak-to-peak amplitude of 10 degrees and a frequency of 0.3 Hz. Every 500 ms the target changed to a different letter. Each time the letter crossed the straight-ahead position, it jumped either forward or backward with an amplitude of 2.5 or 4 degrees. A dual Purkinje image eye tracker was used to track subjects' (N = 4) eye movements at a sampling rate of 357 Hz. Two different tracking conditions were run in blocks, each lasting for 24 seconds and consisting of 8 pursuit cycles with 16 target jumps. In the 'track only' condition subjects were instructed to hold their gaze on the center of the changing letter throughout the course of stimulus motion. In the 'read' condition the subjects were encouraged only to read the changing string of letters. In both viewing conditions, saccadic reaction times were on average 30-40 ms less for saccades to targets in the direction of pursuit compared to the saccades to targets that jumped in the opposite direction. This difference could not be explained by a difference in the amplitudes of forward vs. backward saccades. The results concur with those of previous studies and suggest that attention remains ahead of the pursuit target.

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63.4027 **Hybrid Calibration for Eye Tracking: Smooth Pursuit Trajectory with Anchor Points** Quan Wang[1](quan.wang@yale.edu), Erin Barney[1], Carla Wall[1], Lauren DiNicola[1], Claire Foster[1], Yeojin Ahn[1], Beibin Li[1], Chawarska Katarzyna[1], Frederick Shic[1]; [1]Yale Child Study Center, School of Medicine, Yale University

Conventional eye-tracking calibration use sparse points that require saccades to all locations or pursuit trajectories that require completeness. In this work, we constructed a hybrid calibration system combining smooth trajectory and sparse points and applied it with typically developing (TD) toddlers, toddlers with Autism Spectrum Disorder (ASD) and typical adults. Employing an Eyelink eye tracker in remote mode with 500 Hz, we recorded raw pupil and corneal reflection positions. Single attempt calibrations involved a central fixation point, followed by a circular pursuit trajectory with constant speed and then four points near the screen's corners. First, we used a large circle (diameter: 20 degrees, 5.3 deg/sec) with 10 adult participants, 4 TD toddlers and 4 toddlers with ASD. Each participant had up to 30 internal calibrations. Second, we used a small circle (10 degrees, 2.6 deg/sec) with 9 toddlers with ASD, each with up to 24 internal calibrations. We validated current calibration on next internal calibration dataset. We used a weighted random sample consensus (RANSAC) method to find the best fit of least squares error mapping between the displayed stimuli and recorded raw data on eye position. We weighted the number of samples in the five points and the pursuit trajectory equally. Our results showed that three points plus the circular trajectory was comparable to five-point-calibration. With five points and pursuit trajectory together, the calibration and validation were significantly better than 5-point-calibration alone in all three participant groups and settings ($p < 0.001$ for calibration errors, and $p < 0.05$ for validation errors). With the hybrid calibration system, we created distinct eye movement events and increased sample size, which guaranteed the stability of general geometry on the screen and increased the reliability and accuracy of the screen center area. During single attempt calibration attempts, the hybrid calibration improved calibration results in toddlers and adults.

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63.4028 **Operant reinforcement versus reward expectancy: effects on anticipatory eye movements** Jean-Bernard Damasse[1](jean-bernard.damasse@univ-amu.fr), Laurent Perrinet[1], Jeremie Jozefowiez[2], Laurent Madelain[1,2], Anna Montagnini[1]; [1]Institut de Neurosciences de la Timone, CNRS – Aix-Marseille University, Marseille, France,, [2]SCALab, CNRS-Univ. Lille, CHRU Lille, UMR 9193 - Sciences Cognitives et Sciences Affectives,Lille, France

Previous studies have shown that smooth pursuit can be modulated by reward either during transient target blanking (Madelain and Krauzlis, 2003), or during pursuit of an ambiguous stimulus (Schütz et al, 2015). Moreover, anticipatory smooth pursuit eye movements (aSPEM) are observed before target appearance when predictive information about target motion is available, reducing the typical sensorimotor delay between target motion onset and foveation. By manipulating the probability of target motion direction we previously biased the direction and mean velocity of aSPEM, suggesting that motion-direction expectancy has a strong effect on the initiation of aSPEM. To further understand the nature of anticipatory smooth eye movements, we now investigate different effects of reinforcement on aSPEM with two distinct experiments. In a first experiment, we manipulated the proportion of rewarded trials (signaled by a green-color target associated to a monetary gain) across motion directions (right versus left) in separate experimental blocks maintaining the total number of rightward and leftward trials equal. Our results indicate that the proportion of rewarded trials does not significantly affect anticipatory eye movements. In a second operant conditioning paradigm, the reward was contingent on anticipatory pursuit: in separate blocks with fixed probabilities of rightward (vs leftward) trials, monetary reward was contingent on a criterion-matching anticipatory velocity measured before target motion onset. Contingent monetary reward increased (or decreased) anticipatory velocity compared to the probability-biased condition. To further probe the effects of operant conditioning, we used a yoked-control procedure in a second group of subjects, in which the relation between pursuit and reward was randomized. We observed a reduction of aSPEM mean velocity. Overall, these results strengthen the notion that eye movements (including anticipatory ones) can be considered as an operant behavior, whereas the expectancy for a non-contingent reward cannot efficiently biased them.

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63.4029 **Action video game play increases the connection of pursuit eye movements and dynamic visual processing with visuomotor control** Li Li[1, 2](lili@hku.hk), Raine Chen[1]; [1]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR, [2]Neural Science Program, NYU Shanghai, Shanghai, PRC

Visuomotor control skills (such as driving and flying an air craft) are essential for human survival. An important part of visuomotor learning is to carry out efficient eye movements to discover and utilize the most relevant visual information within complex visual arrays for the control of action (Gibson, 1966). We previously found that action video game play improves visuomotor control of a moving target. Here we examined whether the improvement is related to better pursuit eye movements and processing of dynamic visual motion information. We tested 21 male action gamers and 20 male non-gamers with a manual control task in which they used a joystick to keep a target moving pseudo-randomly along the horizontal axis according to a sum of sinusoidal function (0.1–2.19 Hz) centered on the display. The joystick control dynamics was acceleration control which required participants to primarily rely on target motion information to generate control responses. Action gamers had better control precision, higher response amplitude, and shorter response delay than did non-gamers. We then examined pursuit eye movements and dynamics visual motion processing of these participants using an oculomotor control task in which participants tracked a target that moved according to a step-ramp function with speed randomly sampled from 16°/s to 24°/s and direction randomly sampled from 0° to 360° in 2° increment (Liston & Stone, 2014). Action gamers did not differ from non-gamers in their eye tracking performance. However, action gamers' pursuit initiation, steady-state tracking, direction- and speed-tuning were significantly correlated with their superior control precision (Pearson's r: 0.46-0.60, $p < 0.05$) and shortened response delay (Pearson's r: 0.48-0.61, $p < 0.05$) in the manual control task. No such correlations were found in non-gamers. The improved visuomotor control in action gamers could be due to their improved connection of pursuit eye movements and dynamic visual processing with visuomotor control.

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63.4030 **Involuntary saccades and binocular coordination during visual pursuit in Parkinson's disease** Arash Yazdanbakhsh[1,2](yazdan@bu.edu), Chia-Chien Wu[1,3], Bo Cao[4], Veena Dali[5], Celia Gagliardi[1], Marc Pomplun[6], Alice Cronin-Golomb[2]; [1]Center for Computational Neuroscience and Neural Technology, Boston University, [2]Department of Psychological and Brain Sciences, Boston University, [3]Brigham & Women's Hospital, [4]University of Texas Health Science Center at Houston, [5]Undergraduate Program in Neuroscience, Boston University, [6]University of Massachusetts Boston

Prior studies of oculomotor function in Parkinson's disease (PD) have either focused on saccades while smooth pursuit eye movements were not involved, or tested smooth pursuit without considering the effect of any involuntary saccades. The present study investigated whether these involuntary saccades could serve as a useful biomarker for PD. Ten observers with PD participated in the study along with 10 age-matched normal control (NC) and 10 young control participants (YC). Observers fixated on a central cross while a disk (target) moved toward it from either side of the screen. Once the target reached the fixation cross, observers began to pursue the moving target until the target reached to the other side. To vary the difficulty of fixation and pursuit, the moving target was presented on a blank or a moving background. The moving background consisted of uniformly distributed dots moved in either the same or the opposite direction of the target once the target reached the central fixation cross. To investigate binocular coordination, each background condition was presented under a binocular condition, in which both eyes saw the same stimulus, and under a dichoptic condition, in which one eye saw only the target and the other eye only saw the background. The results showed that in both background conditions, observers with PD made more involuntary saccades than NC and YC during both fixation and pursuit periods while YC and NC showed no difference. Moreover, the difference between left and right eye positions increased over time during the pursuit period for PD group but not for the other two groups. This suggests that individuals with PD may be impaired not only in saccade inhibition, but also in binocular coordination during pursuit.

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Wednesday AM

Perception and Action: Locomotion and navigation

Wednesday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4031 Knowing when to give up: Control strategies for choosing whether to pursue or abandon the chase of a moving target

Brett Fajen[1](fajenb@rpi.edu), Oliver Layton[1], Robert Wild[1]; [1]Cognitive Science Department, Rensselaer Polytechnic Institute

An important but neglected aspect of tasks that involve interception of moving targets on foot is knowing when to stop pursuing a target that is moving too fast to catch. Whether the target is a prey animal in the wild or an opponent on the playing field, chasing an uncatchable target is not only futile but a waste of energy. The aim of this study was to test predictions of various models of how humans choose whether to pursue or abandon the chase of a moving target. Subjects used a steering wheel and foot pedals to pursue a target moving through an open field in a virtual environment, and attempted to intercept the target before it escaped into a thicket of trees (the "safe zone" for the target). They were also instructed to quickly press a button if they perceived that they could not reach the target before it escaped. Target speed, trajectory angle, and initial position were varied such that targets were catchable on some trials and uncatchable on others. After each trial, subjects received a reward (points) if they intercepted the target and a distance penalty based on how far they traveled. The net reward was positive when subjects intercepted the target and negative when they pursued uncatchable targets, but losses were minimized when subjects quickly gave up on uncatchable targets. Subjects' decisions to pursue or give up were consistent with a model that relies on the optically specified minimum speed required to intercept. Models that rely on simpler optical variables that correlate with but do not specify minimum required speed (e.g., change in target bearing angle), were not successful at capturing subjects' decisions. We also compared human behavior against that of an agent that learned a policy through reinforcement learning for maximizing rewards.

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63.4032 Visually guided locomotor planning in children and adults

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How far in advance do humans use visual information to guide locomotion? Paths through everyday environments can commonly include a series of obstacles. Here, by measuring whether the first obstacle in a series is approached differently to a single obstacle, we determine how far in advance the distant obstacles influence locomotion. By comparing children and adults we also ask how this planning develops with age. Fifteen 6-8 year-olds and fifteen adults took part. On each trial the participant walked a path with one, two or three obstacles (separate conditions, presented in random order). Locomotor behaviour was recorded with a 16-camera Vicon motion capture system. Cognitive planning was indexed by performance on a Tower of Hanoi task. When an obstacle was the first in a series, adults crossed it with a shorter trail foot step length and a smaller toe clearance than a single obstacle. Children likewise shortened step length. However, in contrast with adults, they did not modify clearance, but did adjust lead foot step length. A measure of motor planning, calculated as the difference between single and double toe clearances, was not correlated with cognitive planning (Tower of Hanoi performance) at any age. We provide naturalistic evidence in support of recent models (Mattis & Fajen, 2014) which propose that adults make visually- guided adjustments 1-2 steps in advance of obstacle crossing. 6-8-year-old children also make adjustments at this distance or slightly before, but alter different aspects of gait, demonstrating relatively late development in visually-guided locomotion. The results also suggest the independence of cognitive and motor planning abilities at all ages.

63.4033 An Exploratory Approach to Manipulating Dynamic Stability: Investigating the Role of Visual Control during a Precision Foot Placement Task

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Bacgkground: The visual system acts as a feedforward control mechanism during human locomotion. Visual information contributes coordination of the head-arm-trunk (HAT) segment and modulating foot placement. The purpose of this study was to examine the effects of a complex navigational stone-stepping task on HAT segment control and how the visual system guides locomotion during a complex foot placement task. Methods: Nine university-aged females (Mean age: 22.5 years old +/-1.75) participated in this study. Participants were outfitted with four rigid bodies and two IRED markers in order to measure kinematic data, as well as an ASL H7-HS High Speed Head Mounted Optics eye tracking unit to assess gaze behaviour. Participants performed 40 trials across four conditions (e.g. predetermined and self-selected pathways; starting with either the left or the right foot), on a 7.2mx1.2m raised-target platform. Measurements were compared across conditions (e.g. constrained versus unconstrained), time points (e.g. first, middle, and last trial performed of each condition), and segment (one versus two). Results: Findings revealed that there was a significant difference between conditions such that: 1) the constrained vertical pupil RMS velocity was higher than the unconstrained ($F(3,24)=4.71$; $p= .04$; $d=.46$); 2) the unconstrained horizontal pupil RMS velocity was higher than the unconstrained ($F(3,24)=4.40$; $p= .03$; $d=.36$); 3) the constrained average walking speed was greater than the unconstrained ($F(3,24)=23.27$; $p=0.04$; $d=.30$); 4) the constrained trunk pitch was greater than the unconstrained ($F(3,21)=4.84$; $p=0.01$; $d=.45$); and 5) the unconstrained dynamic stability margin minimum was greater than the constrained ($F(3,21)=4.89$; $p= .01$; $d=.41$). Conclusions: During constrained trials, there was evidence to suggest that trunk control had a greater regulation than during unconstrained trials. However, during unconstrained trials, individuals were able to choose footholds based on their current state of stability. Thus, conditional demands influenced gaze behaviour, separating eye movements into vertical or horizontal components.

63.4034 The Influence of Biomechanics on Visual Attention while Walking

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Humans are incredibly stable and efficient walkers. This is true even when walking is performed in simultaneity with a secondary task, such as social interaction, or use of a cell phone. This is impressive because, while visually guided walking relies upon fixations to the ground plane, secondary tasks often require shifts of gaze away from the ground plane. Thus, to remain stable while walking requires the intelligent timing of task dependent gaze shifts to and from the ground plane. However, little is known of how these shifts are timed. Recent investigation has demonstrated a tight relationship between the biomechanics of bipedal gait and the spatial extent of visual information needed for the planning of foot placement. It remains unclear if the biomechanics similarly influence the timing of eye movements to and from groundplane. We investigate using motion capture and eye-tracking to record the gait kinemtaics and gaze adjustments of a subject walking a straight path. During locomotion, a single augmented reality obstacle of three possible heights (0.15, 0.25, 0.35 leg lengths) is projected at a randomized location along the subject's path. The 2D projection of this obstacle is dynamically updated with changes in head position so that the optical information provided by the 2D projection is consistent with that of a 3D obstacle. Illusory height is reinforced through the use of stereoscopic glasses. While walking, the subject also performs a vigilance task involving the identification of numbers within a random sequence displayed at eye height. Task demands ensure that the subjects allocate visual attention to both the primary and vigilance task with equal importance. Analyses demonstrate temporal coupling between the timing of gaze shifts and evolution of the gait cycle.

63.4035 Quantitative Assessment of Gait Instability in the Absence of Visual Information

Chihiro Asanoi[1](citron_nelle@kdr.biglobe.ne.jp), Koichi Oda[2]; [1]Tokyo Lighthouse, [2]Tokyo Woman's Christian University

Walking and reading are two major difficulties in daily life for persons with visual impairments. Their walking instability has been recognized by orientation and mobility specialists, but it is difficult to quantitatively evaluate walking instability as compared with shorter steps. Easy and quantitative evaluation of walking instability in persons with visual impairments is essential to introduce and evaluate effective mobility training. In the present study, whole-body walking instability in the absence of visual information was quantified using a point-light walker (PLW) reconstructed from major joint movements detected by an infrared sensor system (KINECT for Windows). Seven persons (46 ± 14 years old) with normal vision served as walkers in two different conditions—eyes opened and eyes closed. The frontal animation sequences of the PLW were shown by 17 white dots corresponding to the locations of the head and major joints, which were scaled to the same height. Within a step cycle, we measured horizontal and vertical deviations of all point-lights from their mean trajectories. The eyes-closed condition made walking unstable with greater horizontal fluctuations in the frontal view, especially in both hips (right: 4.4 ± 1.8→ 5.4 ± 1.6cm, $p < 0.05$; left: 4.3 ± 1.5→ 5.4 ± 1.5 cm, $p < 0.05$) and the center of gravity (4.2 ± 1.8→ 5.2 ± 1.6 cm, $p < 0.05$). Additionally, vertical movements of the right knee (6.0 ± 2.0→ 4.5 ± 2.3 cm, $p < 0.05$) and right hip (4.1 ± 2.0→ 3.3 ± 1.7 cm, $p < 0.05$) were reduced in the eyes-closed condition. Thus, walking instability in the absence of visual information was quantitatively characterized by an increased lateral sway of hips and the center of gravity. Infrared sensor-aided PLWs could provide an useful tool to gain insight into walking stability control in persons with visual impairments.

63.4036 **Failure of spontaneous phase locking for side-by-side walkers in visual contact** Amanda Elam[1](aelam1@swarthmore.edu), Catherine Norris[1], Greer Prettyman[1], Ray Lefco [1], Frank Durgin[1]; [1]Psychology, Swarthmore College

Do paired walkers with similar stepping frequencies spontaneously synchronize their steps when in visual contact? To examine this question, pairs of students who did not know each other participated in an experiment ostensibly about effects of fatigue on performance. The natural gait ratio (Durgin, Reed, & Tigue, 2007) of each participant was calculated based on a brief period of walking down a measured hallway. Participants were then asked to walk on side-by-side treadmills for five minutes. The speeds of the two treadmills were set based on the measured gait ratios such that the expected stepping frequencies of the two walkers were either similar ("easy" condition) or separated by 12% ("hard" condition). Crossed with this manipulation, instructions were given to half of the pairs of walkers to try to synchronize their steps (no instruction was given to the other half of the walker pairs). To quantify phase locking, we measured the proportion of time participants' steps were within 90° of phase of each other. This value was rescaled assuming that time spent accidentally within 90° of phase would be equal to time spent more than 90° out of phase. Under instructions to synchronize steps, the median percent time spent in phase was 94% (M = 77%) in the easy condition and 28% (M = 36%) in the hard condition. Without explicit instruction, however, spontaneous phase locking was rare in the easy condition (median: 17%; M = 14%), and almost non-existent in the hard condition (median: 0%; M = 1%). The infrequency of phase-locking is surprising. Video-recordings of paired walkers on public walkways suggest that spontaneous synchronization is frequent (60%) when walkers have similar stepping frequencies (Hajnal & Durgin, unpublished data). Given that our participants didn't know each other, social factors may contribute to the emergence (or avoidance) of spontaneous phase-locking.

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63.4037 **The effects of a human confederate and goal location on the path selection of young adults** Lana Pfaff[1](pfaf1880@mylaurier.ca), Michael Cinelli[1]; [1]Kinesiology and Physical Education, Wilfrid Laurier University

INTRODUCTION: The behavioural dynamics model suggests that obstacles correspond to repellers forcing trajectories to diverge, whereas goals act as attractors in which path trajectory converges. However, environmental obstacles are avoided based on characteristics; path trajectories are wider for animate compared to inanimate objects. Nonetheless, the effects of different obstacle properties (animate vs. inanimate) on repulsion forces are unclear. The purpose of this study was to determine whether the attraction of a goal dominates path selection despite obstacle characteristics. METHODS: Participants (N=15) were instrumented with IRED markers (NDI Optotrak) on the head and trunk to calculate the location of the Centre of Mass (COM) over time. Participants were instructed to walk along a 10m path toward a goal located at one of three possible locations: 1) midline of the pathway; 2) 80cm to left of midline; or 3) 80cm to right of midline. Halfway along the pathway three obstacles were placed perpendicular to the pathway consisting of either three vertical poles (20cm diameter) or two vertical poles and a confederate. The obstacles were each separated by 80cm, creating two equal apertures on either side of the midline. The location of the confederate was either: 1) along midline; 2) 80cm to left of midline; 80cm to right of midline; or 4) not present. RESULTS: A stepwise multiple regression analysis was used to test if gender, shoulder width, confederate location, and goal location significantly predicted participants' path selection (i.e., medial-lateral position of COM at time of crossing the obstacles). The results of the regression indicated that goal location explained 48.9% of the variance ($R2=.489$, $F(1,175)=170.6, p< .001$) in path selection ($\beta = .700$, $p< .001$). CONCLUSION: The findings suggest that different obstacle characteristics (animate vs. inanimate) do not affect repulsion but rather the attraction of the goal is what dominates one's path.

Acknowledgement: NSERC

63.4038 **Watch your step! Haptic perception of geographic slant corresponds to vision, but results in safer locomotion** Jonathan Doyon[1](jonathan.doyon@eagles.usm.edu), Joseph Clark[1], Tyler Surber[1], Alen Hajnal[1]; [1]Department of Psychology, University of Southern Mississippi

Vision and haptics play a central role in perceiving environmental layout to guide future actions. Kinsella-Shaw, Shaw, & Turvey (1992) found that observers can perceive the maximal slope that supports upright standing. Hajnal, Wagman, Bunch, & Doyon (2014) demonstrated that visual perception of stand-on-ability is accurate compared to action capabilities; haptic perception of stand-on-ability reliably underestimates action capabilities. This finding contradicts Gibson's (1979) theory of equivalence in perceptual systems: perception should be equivalent regardless of modality. The current experiment offers a direct comparison between visual and haptic perception of stand-on-ability, i.e., one perceptual system is used to measure the other. Two groups of observers provided affordance judgments, confidence ratings, and matching judgments in two conditions: (1) visual perception and haptic matching of a visual stimulus and (2) haptic perception and visual matching of a haptic stimulus. In condition (1), observers viewed a surface set to a discrete angle then attempted to match it with a continuously adjustable haptic stimulus occluded by a curtain. In condition (2), observers felt a surface set to a discrete angle then matched it with a continuously adjustable visual stimulus. Results indicated that visual and haptic perceptions of stand-on-ability are indeed equivalent: no differences were found between visual, haptic, and action boundaries. Matching judgments were highly correlated, showed high internal consistency, and showed high veridical accuracy for angles that fall within the behaviorally relevant range. The current experiment offers support for Gibson's (1979) theory and contrasts with previous investigations of perceptual correspondence where haptic perception consistently underestimates the action boundary (Hajnal et al., 2014): the correlation in haptic matches is nearly identical to visual matches, but with an intercept offset. The multisensory nature of this task promotes equivalence where unimodal tasks as in Hajnal et al. perpetuate differences across systems revealing nonequivalence.

63.4039 **Action strategies for walking through multiple, misaligned apertures** Michael Cinelli[1](mcinelli@wlu.ca), Amy Hackney[2], James Frank[2]; [1]Department of Kinesiology and Physical Education, Wilfrid Laurier University, Waterloo, Canada, [2]Department of Kinesiology, University of Waterloo, Waterloo, Canada

INTRODUCTION: Individuals attempt to equalize the amount of space between the shoulders and obstacles, by walking through an aperture's center. Path selection is determined by goal attraction, individuals walk through the center of an aperture because the attraction is pulling them there. However, it is unclear whether the attraction originates from the aperture's center or the end goal. The purpose of the current study was to decipher the possible location of the attracter, by evaluating crossing behaviour for multiple, misaligned apertures. METHODS: Participants were instructed to walk through three apertures towards an end goal. The first and last aperture widths were coupled and were either 0.9x or 1.7xSW, the second aperture was either 0.9, 1.3, or 1.7xSW and shifted 25, 50, or 75cm from the path's midline. RESULTS: Findings revealed that the attraction of the end goal, and not the middle of the aperture, guided crossing behaviour evident by the fact that the COM position at the time of crossing was closer to the obstacle nearest midline ($F(2, 36) = 362.33$, $p< .001$) and the space between the shoulder and obstacle closest to midline decreased as the shift magnitude increased ($F(2, 36) = 52.47$, $p< .001$). Furthermore, as the middle aperture shift increased, individuals rotated their shoulders more often ($F(2, 36) = 11.25$, $p< .001$) regardless of the aperture size. It is believed that rotations were produced in an attempt to keep one's trajectory as close to the midline as possible because rotations would not normally occur for all aperture sizes when it is aligned with goal. CONCLUSION: Not only does the attraction of the goal guide path trajectory, but individuals reduce the spatial margin and rotate the shoulders when walking through misaligned apertures, likely in attempt to maintain the straightest possible path.

Acknowledgement: NSERC

63.4040 **Finding Home: The influence of landmark ambiguity on human navigation.** Simon Jetzschke[1](sjetzschke@uni-bielefeld.de), Norbert Boeddeker[4], Marc Ernst[3], Julia Fröhlich[2]; [1]Department of Cognitive Neuroscience, Bielefeld University, 33501 Bielefeld, [2]Department of Cognitive Neuroscience, Bielefeld University, 33501 Bielefeld, [3]Department of Cognitive Neuroscience, Bielefeld University, 33501 Bielefeld, [4]Department of Cognitive Neuroscience, Bielefeld University, 33501 Bielefeld

Spatial navigation tasks require us to memorize the location of a goal, using sensory cues from multiple sources. Information about one's position in relation to the goal comes from the kinaesthetic and proprioceptive senses of the human body. Also external reference points, such as landmarks or beacons provide information about the spatial position of the individual in given surroundings. A single landmark provides ambiguous cues if not combined with additional information. How does this ambiguity affect the accuracy and precision in human navigation? To study general mechanisms of landmark navigation we used the same experimental paradigm for two different senses: audition and vision. Participants learned the position of a goal, determined by a varying number of landmarks and were then relocated to a new position from where they had to return to the goal location. We tested the performance (a) with blindfolded participants and auditory landmarks and (b) sighted participants in a virtual-reality setup with visual landmarks. We quantify navigation performance using the distance of trajectory end-points towards the goal. We find that participants were unable to resolve the ambiguity provided by one, two and three auditory landmarks when the landmarks are not individually identifiable. A very similar finding comes from experiments with visual landmarks: the participants' performance is closely linked to the ambiguity of the landmarks. These data support the use of a method called snapshot matching, which is well studied in homing insects. We test this hypothesis against the idea that the participants memorize and use only single individual landmarks. In a second set of experiments we aim to find out how humans select reliable and useful landmarks and what homing strategies they use when uncertain about the information available.

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63.4041 **Effects of familiarity and neighbor behavior on visually-guided exit choice in an emergency** Max Kinateder[1](max_kinateder@brown.edu), Brittany Comunale[1], William Warren[1]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University

The familiarity hypothesis postulates that building occupants are drawn towards familiar places during emergencies (Sime, 1980). 'Movement to the familiar' has been reported during various evacuation incidents, but thus far, has not been studied experimentally. The present experiment investigates how movement to a familiar exit interacts with visual information about a neighbor's egress behavior. Participants walked in a virtual environment while wearing a wireless head-mounted display. On each trial, the participant entered a square room (6.55 m on a side) through a door (the familiar door). The room contained artwork (statue, 2 photographs) as well as two identical doors with emergency exit signs, located either on the same, opposite, or perpendicular walls. Participants were instructed to explore the artwork; when they stood in front of the statue, facing both doors, a fire alarm was triggered. There were nine trials in each of four conditions: (a) In the control condition, the participant was alone in the room. (b) In the passive condition, a virtual human (neighbor) stood near the statue, but ignored the fire alarm. (c) In the familiar condition, the neighbor walked to the familiar door and exited after the fire alarm was triggered. (d) In the unfamiliar condition, the neighbor exited the unfamiliar door. With 15 out of 20 participants tested, the results indicate that participants are significantly more likely to exit by the familiar door than the unfamiliar door ($p < .01$), consistent with the familiarity hypothesis. Movement to the familiar was significantly more likely when the neighbor left by the familiar door ($p < .01$), and less likely in the unfamiliar condition ($p < .05$). The results suggest that movement to the familiar interacts with the social influence of neighbors, and can be reproduced and studied in virtual reality.

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63.4042 **Spatial localization accuracy varies with the fractal dimension of the environment** Arthur Juliani[1](ajuliani@uoregon.edu), Alexander Bies[1], Cooper Boydston[2], Richard Taylor[2], Margaret Sereno[1]; [1]Department of Psychology, University of Oregon, [2]Department of Physics, University of Oregon

Fractal geometry has been utilized as a means of mathematically describing various natural environments ranging from British coastlines to the Wisconsin wilderness. Despite the use of fractal geometry in environmental analysis, it has yet to be studied systematically in human navigational research. In order to establish a relationship between the fractal dimension of a natural landscape and humans' ability to navigate such spaces, we conducted an experiment using virtual environments that simulated the fractal properties of nature. In this experiment, participants were instructed to explore a series of circular island environments by controlling a virtual avatar from a first person perspective. The island environments were generated such that the feature edges were of fractal dimensions (D) varying from 1.0 to 1.9, and the surface of the environment extended into three dimensions. Overlaid in the displayed environment was a map describing both the environmental topography, as well as the location of a target in the environment, indicated with a red dot. Participants were instructed to move their avatar to the area of the island they believed corresponded to the target on the map and press a button to indicate their arrival at the target's position. Twenty-two participants completed the task, with a mean of 65 trials completed each. Mean accuracy score was found to be highest on trials where the environment was within the fractal dimension range of $D = 1.1\text{-}1.5$, and indicative of uninformed guessing at $D=1.0$ and $D=1.9$. The low-to-mid range of fractal dimension that we find optimal here has previously been found to elicit high aesthetic ratings. This evidence supports a visual fluency theory in which there is an optimization of processing spatial information within the low-to-mid fractal dimension range.

63.4043 **Where did I leave my coffee cup? Evidence for independent local and global representations of environmental space** Steven Marchette[1](stevenmarchette@gmail.com), Jack Ryan[1], Russell Epstein[1]; [1]Department of Psychology, University of Pennsylvania

To successfully navigate to a target, one must represent its location at multiple spatial scales. For example, to find a favorite coffee mug requires remembering that it is in one's office and in the back corner. An intuitive hypothesis is that we accomplish this task by accessing the same representation at progressively finer levels of granularity—first remembering the general location and then "zooming in." Here we provide evidence for a different view, in which independent representations are used for different spatial scales. Subjects in 7 experiments learned the location of objects positioned within four visually-distinct but geometrically-identical buildings that were situated within a broader virtual park. They were then tested on their knowledge of object location by asking them to navigate to the remembered location of each object. We examined errors during the test phase for confusions among geometrically analogous locations in different buildings—that is, navigating to the right location in the wrong building. We observed that subjects frequently made these confusions, which are analogous to remembering a passage's location on the page of a book but not remembering the page that the passage is on. This suggests that subjects were recalling the object's local location without recalling its global location. Further manipulations indicated that geometric confusions were observed even between buildings that were not metrically identical as long as geometrical equivalence could be defined. However, removing the walls so that the larger environment was no longer divided into subspaces abolished these errors entirely. Taken together, our results demonstrate that human spatial memory contains two separable representations of "where" an object can be found: (i) a schematic map of where an object lies with respect to local landmarks and boundaries; (ii) a representation of the identity of each local environment.

63.4044 **Landmark- and boundary-based spatial memory: typical and atypical development** Frederik Kamps[1](fkamps@emory.edu), Joshua Julian[2], Jack Ryan[2], Russell Epstein[2], Daniel Dilks[1]; [1]Department of Psychology, Emory University, [2]Department of Psychology, University of Pennsylvania

Prior work has revealed that spatial memory is supported by two distinct systems: one in the striatum for encoding locations relative to landmarks, and the other in the hippocampus for encoding locations relative to environmental boundaries. Although abundant research supports this distinction in adult animals and humans, less is known about its development–whether its foundations can be detected early in typical development, whether it undergoes significant developmental change, and whether the two systems show differential impairment in cases of atypical development. Here we examined landmark- and boundary-based memory in typically developing (TD) children (6, 8, and 10 y/o), TD adults, and adults with Williams syndrome (WS)–a rare developmental disorder with hippocampal abnormalities. Participants performed a virtual navigation task that required them to learn the locations of objects within an arena comprising a landmark, a circular boundary, and distal cues (mountains) for orientation. The objects were tethered to either the landmark or boundary, and the relative position of the landmark and boundary was intermittently changed, allowing learning of landmark and boundary object location to be independently assessed. In typical development, we found increasing performance with age for both landmark-tethered and boundary-tethered objects; however, landmark-tethered object performance was similar to adults by

10 y/o, while boundary-tethered object performance in 10 y/o's was still below that of adults. In atypical development, we found that WS adults performed remarkably similar to TD adults on landmark-tethered objects, but significantly worse on boundary-tethered objects—in fact, similar to 6 y/o's. Taken together, these findings demonstrate that the cognitive systems mediating landmark- and boundary-based spatial memory i) develop under different trajectories, with the boundary-based system lagging behind the landmark-based system, and ii) are differentially susceptible to breakdown, with the boundary-based system more vulnerable than the landmark-based system, providing causal evidence for this distinction in humans.

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63.4045 **Navigation and spatial memory for older adults with simulated low vision** Erica Barhorst[1](erica.barhorst@psych.utah.edu), Kristina Rand[1], Sarah Creem-Regehr[1]; [1]University of Utah

Research suggests that spatial learning while navigating with severely degraded vision (simulated reduced acuity and contrast sensitivity) demands the use of limited cognitive resources for normally-sighted young adults (Rand, Creem-Regehr, & Thompson, 2015). In a series of studies, we examined how the same severely degraded vision during navigation influences spatial memory for healthy older adults (age 60+). In Study 1, normally-sighted older adult participants walked on novel real-world paths wearing goggles that simulated severely reduced visual acuity and contrast sensitivity or navigated with their normal vision, and were asked to remember the location of landmarks. At the end of each path, they pointed to target locations using a verbal reporting measure. Results suggest that participants performed significantly worse on the memory task (greater pointing error) in the low vision condition compared to their performance with normal vision, replicating previous work with young adults. In Study 2, we tested the hypothesis that navigating with severely degraded vision results in increased cognitive load, and that this cognitive load can be offset by providing physical guidance to the participant to reduce mobility monitoring. Normally sighted older adult participants walked the same four paths with degraded vision, either with guidance (holding onto the experimenter's arm) or without guidance. Preliminary results suggest that guidance improves spatial memory, showing reduced pointing error compared to the non-guidance condition. We will discuss possible accounts to explain the memory impairment at this severe level of visual impairment and propose future work exploring age differences in older adulthood and studies of individuals with clinical low vision.

Acknowledgement: National Eye Institute of the National Institute of Health

63.4046 **Visual and motor uncertainty effects on obstacle avoidance trajectories.** Oran Zohar[1](oran_zohar@utexas.edu), Matthew Tong[1], Mary Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Subjects lack perfect knowledge about the world, so to understand behavior, it is necessary to take subjects' uncertainty into account. Sprague et al (2007) suggested that gaze is directed to locations in order to resolve uncertainty affecting task performance, with uncertainty about unattended parts of the scene increasing over time. This uncertainty can be due to intrinsic factors (like motor noise and imperfect memory) and extrinsic factors (a dynamic world state). We evaluated the consequences of intrinsic and extrinsic uncertainty, revealed in the behavioral choices subjects made while walking through a cluttered scene. Subjects followed a path in a virtual environment while intercepting targets and avoiding obstacles. Extrinsic uncertainty was manipulated by adding random motion to targets and obstacles. We examined gaze and walking behavior of 12 subjects while they avoided obstacles. We plotted a subject's path from the time that fixation on an obstacle ended, and measured the minimal distance at which the subject subsequently passed the obstacle. When obstacles are stationary subjects give wider clearance when fixation had ended at a greater distance. Modal clearance was 0.42m for fixations ending with obstacles about 0.4m away, increasing to 0.55m for fixations that ended when the subject was further than 2.25m. This suggests that subjects take into account their intrinsic uncertainty, which accumulates over the greater distance walked after fixation ended. When the obstacles were moving, the distance of the last fixation had a greater effect (increasing to 0.64m clearance at large distance), suggesting that the extrinsic uncertainty about scene state is also taken into account. Together, this suggests that both kinds of uncertainty are taken into account when planning path trajectories (consistent with the decision-theoretic account described by Wolpert and Landy, 2012), and also that the position of the obstacle is only imperfectly updated when it is not fixated.

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Face Perception: Emotion 2

Wednesday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4047 **Compound facial threat cue perception: Contributions of visual pathways, aging, and anxiety** Reginald Adams[1](rba10@psu.edu), Hee Yeon Im[2], Cody Cushing[2], Noreen Ward[2], Jasmine Boshyan[3], Troy Steiner[1], Daniel Albohn[1], Kestutis Kveraga[2]; [1]Department of Psychology, College of the Liberal Arts, The Pennsylvania State University, [2]Department of Radiology, Massachusetts General Hospital, Harvard Medical School, [3]Department of Psychology, College of Arts and Sciences, Brandeis University

Gaze direction and facial emotion can provide important cues about danger in the environment and are processed in what appears to be a functionally interactive and adaptive manner. Previous work has also revealed important individual differences in responses to compound threat cues. For instance, Individuals with high state anxiety showed increased amygdalar response to clear threat cues, while those with low anxiety were more sensitive to ambiguous threat cues (Ewbank et al., 2010). The effects of aging on the brain are another relevant factor to consider in this integrative process. In a large (N=131) fMRI study, we tested contributions of magnocellular (M) and parvocellular (P) pathways to threat cue integration, and examined how aging and anxiety influence processing. Participants (aged 18-71) viewed images of fearful or neutral faces with direct and averted gaze for one second presentations. These stimuli were presented in high luminance contrast (Unbiased), low luminance contrast (M-biased), or isoluminant red/green (P-biased) images. Overall, a clear threat cue (averted gaze fear) compared with a more ambiguous threat cue (averted gaze neutral) activated both amygdalae. We found that M-biased stimuli activated the right amygdala for ambiguous (fear with direct gaze) vs. clear (fear with averted gaze) threat cues. The older cohort (age >50) showed greater activation in the amygdala and cortical face network to clear threat cues, while the younger cohort (age < 40) had more overall activation to threat ambiguity. Further, right amygdala activity in the older cohort positively correlated ($p < 0.022$) with state anxiety. Finally, high-anxiety subjects showed greater left amygdala activation to clear threat, while low-anxiety participants had increased bilateral amygdala activity to ambiguous threat. These findings suggest that perception of clear vs. ambiguous facial threat cues has different emphases in the M and P pathways, and interacts with perceivers' age and anxiety levels.

Acknowledgement: This work was supported by grant # R01 MH101194 awarded to KK and RBA

63.4048 **Crowd emotion perception is lateralized in a goal-driven fashion and modulated by observer anxiety and stimulus characteristics: behavioral and fMRI results** Hee Yeon Im[1](him3@mgh.harvard.edu), Daniel Albohn[2], Troy Steiner[2], Reginald Adams[2], Kestutis Kveraga[1]; [1]Department of Radiology, Harvard Medical School / Massachusetts General Hospital, [2]Department of Psychology, The Pennsylvania State University

The emotional tone of a crowd of faces (e.g., whether friendly or threatening) guides our interactions with groups of people. However, little is known about the behavioral and neural bases of these socially important influences. Here we examined in 5 experiments how intrinsic factors, such as observers' goal (to avoid or approach) and anxiety level, and extrinsic factors, such as whether the faces were male or female and where they were presented spatially, affect crowd emotion perception and their underlying neural responses. Participants viewed two crowds of emotional faces in the left and right visual fields for 1 second (Fig.S1) and reported which crowd they would avoid (Exp.1-2) or approach (Exp.3-4). In Exp.5, a new cohort (N=24) was scanned with fMRI while they performed the avoidance task. Although it is thought that right hemisphere (RH) dominates perception of negative stimuli, and left hemisphere (LH) is dominant for positive stimuli, we found significant RH dominance for both angrier and happier crowds depending on task goal, avoidance and approach, respectively (Fig.S2). This finding suggests that RH dominates processing of task-congruent crowd emotion, irrespective of its valence. High-anxiety participants showed faster RTs overall and lower accuracy for happier, but not angrier, crowds. While the observers' sex had no effect, we found that crowds of happy females and angry males were perceived more accurately. Finally, fMRI results revealed greater RH activation while perceiving task-congruent, angry crowd during the avoidance task, with higher activation in the ROI's including amygdala, hippocampus, and face-sensitive cortex, compared with the corresponding regions in LH. When a happier crowd, incongruent for the avoidance task, was presented to RH, we found higher activation in the corpus callosum suggesting increased inter-hemispheric communication. In conclusion, perception of crowd emotion is substantially RH-lateralized and strongly modulated by task, stimulus characteristics, and observer anxiety.

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63.4049 **State Anxiety and Perception of Average Emotion in Groups of Faces** Sarah Caputo[1](secaput@ilstu.edu), Amrita Puri[1]; [1]Department of Psychology, Illinois State University

Threatening stimuli, such as fearful or angry faces, have been shown to attract visual attention. Previous findings have suggested that this attentional bias is even greater for adults with high levels of anxiety-related traits. Additional research suggests that more socially anxious individuals tend to perceive overall emotions in groups of faces as more negative than less socially anxious individuals. In relation to general anxiety-related traits, there is evidence that more anxious individuals are more accurate in identifying the average emotion for groups that contain fear. However, less is known about how perception of group-emotion may be affected by transient, state-dependent anxiety. The present study investigated the relationship between state anxiety and the perception of the average emotion of crowds of faces. We hypothesized that inducing transient anxiety via anticipation of a public-speaking task would lead to estimating the average emotion of groups of faces as more fearful than it actually is. Participants completed a short-form State-Trait Anxiety Inventory (STAI) state subscale to establish a baseline level of state anxiety, and were then randomly assigned to an experimental condition, in which they were given a few minutes to prepare a public speech, or a control condition, in which they prepared a short essay on a chosen topic. Participants then completed a second short-form STAI before completing a computer-based task requiring estimation of the average emotion of groups of faces. Results show that anticipation of presenting a speech led to increased state anxiety, but this transient anxiety did not appear to bias estimates of group emotion towards fear. However, higher state anxiety was related to decreased estimation accuracy for groups of faces with negative (i.e., fearful and sad) but not positive (i.e., happy) average emotions.

63.4050 **Contribution of Top and Bottom Part of a Face to the Perception of Facial Expressions: A Gaze-Contingency Investigation** Vicky Chen[1,2,3](percepccu2013@gmail.com), Gary Shyi[1,2,3]; [1]Department of Psychology, National Chung Cheng University, [2]Center for Research in Cognitive Sciences, National Chung Cheng University, [3]Advanced Institute of Manufacturing with HIgh-tech Innovations, National Chung Cheng University

It is widely believed that face recognition is achieved via holistic processing of the representation integrated over parts of a face. In contrast, processing of facial expressions can be undertaken based on representation of separate parts. In three experiments we examined contribution of top and bottom part of a face to the perception of facial expressions. In Experiment 1, we examined the role that top and bottom part of a face may play in perceiving emotional expression by combining an expressive half with an emotionally congruent half or a neutral half, in comparison to a half face being presented alone. Results showed the bottom part of a face (typically with a smiling mouth) played a dominant role in expressing happiness, whereas the top part appeared to play an influential role in expressing sadness. For the remaining expressions, neither the top nor bottom part played a distinct role. In Experiment 2, we employed gaze contingency to (a) replicate the findings by Calvo and his colleagues that a smiling mouth could dominate the perception of happy expression (Calvo, Fernández-Martín, & Nummenmaa, 2013), and (b) extend the finding to see whether the top half would play a similar role in the perception of sad expression. The results, while replicating Calvo et al.'s overall findings, revealed that the role of top part in expressing sadness was less straightforward. Finally, in Experiment 3, we explicitly directed participants' attention to the top part of a sad face and found that the top part required focal attention in order for it to affect the expression of sadness. Taken together, these results suggest that the contribution of top and bottom part of a face to the perception of facial expression may vary between holistic and part-based processing, depending upon the nature of specific emotions to be conveyed.

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63.4051 **Processing emotion across the senses: hearing negative emotional content weakens the perceptual and physiological response to seeing a happy face** Vivian Ciaramitaro[1](vivian.ciaramitaro@umb.edu), Anh Phan[1], Hannah Lapp[1], Richard Hunter[1], Daniel Harris[1]; [1]Department of Psychology, Developmental and Brain Sciences, University of Massachusetts Boston

Faces convey a wealth of information, cueing us to features such as the gender, identity or emotional status of individuals, and providing crucial signals for navigating social interactions. We examined the extent to which emotionally charged voices alter the emotion seen in a face and the corresponding physiological stress response. We used face adaptation to quantify perceptual shifts when seen and heard emotions were congruent (angry faces and angry voices or happy faces and happy voices) versus incongruent (angry faces and happy voices or happy faces and angry voices). We hypothesized adapting to congruent visual and auditory emotions would yield stronger perceptual shifts compared to incongruent emotions. For each of 40 participants (students from the University of Massachusetts Boston, ages 18-27) we quantified (1) the neutral point, pre- and post-adaptation, by fitting data with a cumulative normal to determine where faces were equally likely to be judged happy or angry, and (2) the physiological stress response, pre- and post-adaptation, by measuring salivary cortisol during testing. We found that adaptation effects were stronger for happy compared to angry faces and for congruent versus incongruent emotions within each category. Furthermore, the cortisol stress response showed complementary changes, with stronger effects, greater decreases in cortisol, after adaptation to happy compared to angry faces, and with physiological trends mirroring behavioral trends for congruent versus incongruent conditions. These normative measures are first steps towards assessing how such mechanisms may malfunction in social anxiety, extending current evidence from our lab suggesting basic mechanisms of visual adaptation to the emotional content of a face are altered in social anxiety (Ciaramitaro et al, in preparation).

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63.4052 **Object substitution masking prevents within-hemifield perceptual averaging of facial expressions** Elric Elias[1](elric.elias@gmail.com), Lauren Padama[1], Timothy Sweeny[1]; [1]Department of Psychology, University of Denver

Object substitution masking (OSM) is a powerful tool for limiting visual awareness. Behavioral work demonstrates that OSM disrupts, but does not eliminate basic representation of object size. However, OSM does appear to wipe out face- and shape-specific brain activity, as measured by EEG and fMRI. This suggests that OSM is particularly strong late in visual processing, at or just prior to high-level face representation. We sought to test this hypothesis behaviorally, particularly because faces sometimes exert surprising perceptual effects when suppressed from awareness by other types of masking. We leveraged an effect based on the poor spatial resolution of ventral-visual neurons to evaluate how strongly OSM disrupts face processing. When two emotional faces fall within a visual hemifield and selective attention is not deployed, people tend to see the average of those two faces. This perceptual averaging does not occur when two faces appear across visual hemifields, consistent with the receptive field sizes of high-level ventral visual neurons. If OSM disrupts face representation in addition to disrupting awareness, then this averaging process should be reduced when one face from a pair is suppressed by OSM. Observers viewed one neutral and one emotional face (happy/angry) for 20-ms, arranged either vertically to the left/right of fixation (within-hemifield) or horizontally above/below fixation (across-hemifields). On some trials, a trailing four-dot mask limited visual awareness of one face from each pair. On all trials, a subsequently presented arrow prompted observers to indicate how positive or negative one of the faces appeared to be, and to indicate how many faces they perceived. Without OSM, only faces within a visual hemifield were perceptually averaged, replicating previous work. This averaging did not occur when awareness of one face was suppressed by OSM. Behavioral and physiological evidence thus agree—OSM is particularly strong in late stages of visual processing.

63.4053 **Object substitution masking is engaged relatively early in visual processing of emotional faces** Larissa D'Abreu[1](larissa.dabreu@du.edu), Timothy Sweeny[1]; [1]University of Denver

Object substitution masking (OSM) is an effective technique for limiting visual awareness of objects, including faces. Although OSM is thought to be engaged relatively late in visual representation, it is unclear whether it affects some higher-level visual processes more than others. Emotion perception is comprised of emotion detection (determining whether an emo-

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tion is present), and expression discrimination (categorizing that emotion). Because these processes are independent and depend on different facial information, it is possible that they may be differently impaired by OSM. We thus sought to clarify the timecourse of OSM for these two processes. Observers viewed four simultaneously presented faces, each of which was surrounded by four black dots and presented for 20-msec. Three of the faces were neutral, whereas the fourth face (the target) displayed an angry, happy, fearful or neutral expression. The location and the emotion of the target face were randomly selected on each trial. A red four-dot mask remained on the screen at the location of the target for 20, 60, 120, 240, or 640-msec after the faces disappeared. These masking dots served to disrupt perception of the target face, and to cue observers to report its expression. We separately evaluated the extent to which masks shown for increasingly long durations influenced the processes of emotion detection and expression discrimination. We found that OSM disrupted both emotion detection and expression discrimination. Notably, both processes were maximally disrupted with mask durations of 240-msec — roughly the same temporal profile observed in previous investigations of basic shape perception. However, unlike with shape perception, perception of emotion did not recover with longer mask durations, suggesting that once emotion is successfully masked by OSM, it is difficult to recover. Our results suggest that OSM is fully implemented at or prior to the beginning stages of emotion analysis.

63.4054 **Effect of Visual Acuity and Duration of Dynamic Facial Expression on Perceived Emotion** Terumi Otsukuni[1](g07c026@gmail.com), Koichi Oda[2]; [1]The Graduate school of Tokyo Woman's Christian University

Perception of emotions in facial expressions is known to be difficult in some low-vision cases. However, research has shown that this difficulty correlated more to reading performance than to visual acuity (Bullimore et al.,1991). In a face-reading study, the critical face recognition size (CFS) was measured in a method similar to how critical print size for reading text is measured by MNREAD (Miyazaki, 2008). Indeed, Bould et al.(2008) showed that a dynamic face stimulus made perception easier. We investigated how dynamics and observers' visual acuity affect perception of emotions in stimulus sizes smaller and larger than CFS. Stimuli were movies of facial expressions that changed from neutral to one of four emotions (happiness, anger, surprise, and sadness) with maximum intensity. Dynamic conditions varied by 100, 200, 400, 800,and 1600ms. Observers' visual acuity was artificially controlled with occlusion foils to 0.2 and 0.4 in decimal acuity. Face stimuli were presented in three sizes: the first was smaller than, the second was about the same as, and the third was greater than each observer's CFS. Fourteen undergraduate students with normal acuity (>= 1.0) participated, and observers evaluated the perceived intensity for four basic emotions on a five-point scale. CFS showed systematic increase according to decreased acuity levels. For all visual acuity levels, perceived emotion was the strongest for the same category of facial expression when the size was greater than CFS, whereas it was very difficult to specify the category of emotion,and confusion with the other emotions often occurred when the size was smaller than CFS. As for stimulus duration, happiness, anger, and surprise were perceived as being stronger for shorter durations, whereas perceived intensity of sadness was greater for longer durations. This concurred with Bould et al.'s(2008) result. In face sizes smaller than CFS, the intensity of perceived emotions increased with the stimulus duration.

63.4055 **Color changes in facial expressions of emotion are consistent within emotion and differential between emotions** Aleix Martinez[1](aleix@ece.osu.edu), C. Fabian Benitez-Quiroz[1], Pamela Pallett[1], Angela Brown[1], Delwin Lindsey[1]; [1]The Ohio State University

Human faces are colorful, and specific local changes in luminance and chromaticity occur when a person expresses emotion. The relatively small amount of hair on our faces and the three types of cone cells in our retina allow us to perceive the skin color changes that accompany the expression of emotion (Changizi, et al., 2006). Despite the importance of color vision to humans, there is a surprising gap in our understanding of the role of color vision in the perception of facial expressions of emotion. Here, we examine the hypothesis that specific modulations of facial chromaticity and luminance are correlated with the expression of each emotion category, and that these color changes are different between emotion categories. We analyzed the images of more than 184 individuals, who displayed twenty-one distinct basic and compound facial expressions of emotion. For each individual, we computed the chromatic and luminance changes from their neutral expressions to the apices of the 21 emotions in MacLeod-Boynton (1979) space. Machine learning algorithms then identified color changes that were consistently used in the expression of a particular emotion, and were different from those seen in other emotions. A ten-fold cross-validation analysis demonstrated that the identified color patterns can discriminate the images of the 21 emotion categories with about 52% accuracy (chance: 4.7%). These color features also provided information independent from that of Gabor filters and shape features, which are the image features most typically used in models of the visual analysis of facial expressions of emotion. We also examined the role the different color components related to each emotion category, which provided information on the possible role of low-level chromatic and achromatic channels in the subsequent neural processing of the face images of different emotions.

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63.4056 **The Not Face: From the expression of emotion to grammatical function** C. Fabian Benitez-Quiroz[1](benitez-quiroz.1@osu.edu), Ronnie Wilbur[2], Aleix Martinez[1]; [1]The Ohio State University, [2]Purdue University

Facial expressions of emotion are thought to have evolved from the development of facial muscles used in sensory regulation and later adapted to express moral judgment. Negative moral judgment includes the facial expressions of anger, disgust and contempt. Here, we study the hypothesis that these facial expressions of negative moral judgment have further evolved into a facial expression of negation regularly used as a grammatical marker in human language. Specifically, in Experiment 1, we show that people from different cultures expressing negation activate the same facial muscles as those employed to express negative moral judgment. This newly discovered expression of negation (which we call the "not face") was consistently identified in over 400 spoken and signed sentences in English, Spanish, Mandarine Chinese and American Sign Language (ASL). In Experiment 2, we further our previous analysis to show that this nonverbal signal is used as a co-articulator in spoken languages and that, in ASL, it has been grammaticalized as a non-manual marker. Finally, in Experiment 3, we demonstrate that this facial expression of negation exhibits the theta oscillation (3-8 Hz), which is a universal property in syllable and mouthing production in speech and signing (Chandrasekaran et al., 2009; Wilbur & Nolen, 1986). These results hence provide the first evidence for the hypothesis that some components of human language have evolved from sensory regulation and the expression of emotion, providing a possible evolutionary route for the emergence of grammatical markers in human language.

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63.4057 **Face Aftereffects following Perception and Imagery of Gender and Expression** Edoardo Zamuner[1](e.zamuner@gmail.com), Matt Oxner[1], William Hayward[1,2]; [1]School of Psychology, University of Auckland, [2]Australian Research Council Centre of Excellence in Cognition and its Disorders, University of Western Australia

Visual mental imagery is thought to activate many of the same neural mechanisms involved in visual perception. To what degree does the process of imagining a face share neural mechanisms with visually perceiving the same face? Extant work using adaptation paradigms to investigate the neural correlates of perception and imagery of faces has yielded inconsistent results. While some studies report typical aftereffects for perception and imagery (i.e. test faces appeared less like the adaptors after perceiving and imagining faces), others have observed typical aftereffects for perception (i.e. androgynous test faces appeared more male after perceiving females), but atypical aftereffects for imagery (i.e. androgynous test faces appeared more female after imagining females). The present study examined aftereffects following perception and imagery of faces, while controlling for possible task and design confounds. Experiment 1 tested gender aftereffects, and found typical aftereffects for perception and imagery, as in both tasks the perceived gender of androgynous test faces was biased away from the gender of the adaptors. In Experiment, 2 we used the same paradigm to investigate adaptation to perception and imagery of facial expressions of emotions. Our findings indicate that within-emotion adaptation to perceived and imagined expressions generated similar aftereffects, for they both biased perception of neutral-emotional test expressions away from the emotion category of the adaptor. Taken together, our results show that imagery of facial gender and expression recruits the same neural mechanisms that are active during perception of these facial attributes.

63.4058 **Revealing perceptual tuning functions to facial expression of various intensities by means of fast periodic visual stimulation** Arnaud Leleu[1](arnaud.leleu@u-bourgogne.fr), Milena Dzhelyova[2], Bruno Rossion[2], Karine Durand[1], Benoist Schaal[1], Jean-Yves Baudouin[1]; [1]Centre des Sciences du Goût et de l'Alimentation – UMR 6265 CNRS – UMR 1324 INRA – Université Bourgogne Franche-Comté, Dijon, France, [2]Université Catholique de Louvain (UCL) – Institut de Recherche en Sciences Psychologiques (IPSY), Louvain-la-Neuve, Belgium

Perceiving emotional expressions from faces is essential for social interactions. However, while the intensity of facial expressions is highly variable in everyday-life, perceptual tuning to facial expression of various intensities remains largely unknown. Here we recorded scalp electroencephalogram (EEG) from 18 adult participants during fast periodic visual stimulation (FPVS): 100-sec sequences presenting an individual neutral face at a rapid rate of 6 Hz. Expressive faces displaying anger, disgust, fear, happiness, or sadness (one emotion per sequence) were introduced every five faces (i.e., at an oddball rate of 1.2 Hz). During each sequence, the intensity of the 1.2 Hz expression-change increased every 20 secs in 20% steps. A frequency-domain analysis of the whole EEG epoch showed a medial-occipital response at the 6 Hz base rate and its harmonics. The 6 Hz amplitude decreased with increasing intensity steps (i.e., along the sequence), indicating adaptation to low- (e.g., luminance) and/or high-level (e.g., individual face) visual cues that repeated at 6 Hz. In contrast, and most importantly, the 1.2 Hz oddball frequency and its harmonics revealed an expression-change specific activity already at 40% of intensity for all facial expressions except sadness, and increasing in amplitude with increasing intensity steps mainly over right occipito-temporal sites. Interestingly, a time-domain analysis revealed that early expression-change specific activities (peaking at 140 and 250 ms after stimulus-onset) linearly increase with intensity steps whereas a later response (peaking at 370 ms) shows a more abrupt sensitivity to expression-change intensity, suggesting early gradual expression-change detection followed by categorical facial expression perception. Overall, thanks to FPVS-EEG, we isolate objective markers of sensitivity to changes of facial expression and provide new insights into the temporal dynamics and tuning functions of this critical visual categorization ability for efficient social functioning.

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63.4059 **Perceptual learning reveals the relationships among the processing of six basic emotional expressions** Yingying Wang[1](yywang0415@163.com), Fang Fang[1,2,3,4]; [1]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China, [2]Department of Psychology and Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China, [3]Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, China, [4]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing, China

The categorization of human emotion has remained one of the longest standing debates in the biological and social sciences. Despite the fact that emotions are recognized and expressed universally in six discrete categories (anger, disgust, fear, surprise, happy, and sad), researchers have argued that there might be more basic dimensions or units than the six categories. Here, we employed a perceptual learning procedure to investigate the relationships among the visual processing of the six emotions. Human subjects were trained on an emotion detection task, in which an emotional and a neutral face were presented successively in a random order. Subjects needed to identify the interval in which the emotional face was presented. The faces had a fixed contrast and were embedded in noise with different levels of contrast so that the detection threshold was quantified by the face/noise contrast ratio at which detection performance was 82% correct. Each subject was trained on one emotion for six days. Before and after training, we measured their detection performance on all the six facial expressions. Results showed that training on one facial expression improved performance not only on the trained expression, but also on other untrained expressions. Specifically, training on disgust detection improved the detection on anger, and vice versa; training on fear detection improved the detection on surprise, and vice versa. Such two-way improvements suggest similar neural mechanisms underlying their processing. Furthermore, we found that happiness detection was improved by training on all the six emotions but sadness detection was improved only by training on itself. These findings indicated that happiness might share some components with other emotions, while sadness was separated from other emotions. Therefore, the current study provides new insights to the structure of human emotion, suggesting that the six "basic" emotions might be composed of more basic units.

63.4060 **Emotion specificity of gaze cueing in a danger vigilance context.** Abbie Coy[1](acoy@brocku.ca), Catherine Mondloch[1]; [1]Department of Psychology, Brock University

In attentional cueing paradigms in which gaze direction of emotional faces serve as the cue, the magnitude of the cueing effect varies with emotion and context (e.g., threat-related; Dawel et al., 2015; Bayliss et al., 2010). In these studies, however, only two emotions were compared, making it difficult to ascertain whether the influence of emotion is highly specific (e.g., to fearful faces in a threat context) or generalises to other emotions of similar valence or arousal. To examine this question we used a Posner style cueing task in which the gaze direction of a range of emotional faces, namely happy (positive, high arousal), sad (negative, low arousal), angry, fearful, disgust (all negative, high arousal) provided non-predictive cues to the location of a forthcoming threatening or neutral target. We set a danger vigilance context by asking participants (n=64) to indicate whether each target animal was dangerous. Controlling for state anxiety (STAI), gaze cueing was significant for all emotions, ps< .001, but varied across them ps< .01. To examine the influence of valence we used happy (M=38ms) as the reference category; only sad faces differed (M=31ms), eliciting a smaller cueing effect. To examine the influence of arousal we used sad as the reference category; disgusted (M=34ms), fearful (M=47ms), and happy faces elicited larger cueing effects, with no difference for angry faces (M=32ms). These results suggest that in the context of multiple emotions cueing effects are complex. Happy faces and faces indicating indirect proximal threat (disgust, fear) showed comparable gaze cueing compared to merely negative faces (sad), with direct threat (angry) having an intermediate effect. Our findings suggest that in a threat context cueing effects are not limited to threat-related or negative emotions, but generalise across all high-arousal emotions. We are currently investigating whether this pattern holds in other contexts (e.g., pleasant, disgust-inducing).

Acknowledgement: SSHRC

63.4061 **Eye movements and spatial frequency utilization during the recognition of static and dynamic facial expressions** Camille Saumure Régimbald[1,2](sauc14@uqo.ca), Daniel Fiset[1,2], Caroline Blais[1,2]; [1]Département de psychologie et psychoéducation, Université du Québec en Outaouais, [2]Centre de Recherche en Neuropsychologie et Cognition, Département de Psychologie, Université de Montréal

Previous studies have revealed that dynamic facial expressions are better recognized (e.g. Ambadar et al., 2005), and are processed in partially different brain areas (e.g. Schultz & Pilz, 2009), than static expressions. Still unknown is if the visual strategies underlying the recognition of dynamic and static expressions differ. Here, the ocular fixation pattern (Exp. 1) and spatial frequency (SF) utilization (Exp. 2) of 20 participants were measured with static and dynamic expressions. In both experiments, participants categorized pictures or videos (block design) of the six basic facial expressions and neutrality. In Exp. 1, the stimuli were presented unaltered and in Exp. 2, they were randomly filtered using SF Bubbles (Willenbockel et al., 2010). In both experiments, stimuli were presented for a duration of 500 ms. Fixation patterns were analyzed using iMap4 (Lao, et al., 2015). A repeated measures ANOVA revealed a main effect of condition ($p < 0.05$), indicating more fixations on the eye area with static than dynamic expressions, and more fixations on the nose area with dynamic than static expressions. SF tunings were obtained by conducting a multiple regression analysis on the random SF filters and accuracies across trials. Statistical thresholds were found with the Stat4Ci (Chauvin et al., 2005). A SF band peaking at 17.7 cycles per face (cpf) with a full-width-half-max (FWHM) of 30.3 cpf, and a SF band peaking at 16.0 cpf with a FWHM of 29.0 cpf, were found with static and dynamic facial expressions, respectively. SF between 3.7 and 5.7 cpf were more utilized with dynamic than with static expressions, and those between 18.7 and 27.3 cpf were more utilized with static than with dynamic expressions ($p < 0.025$). Together, these results suggest that the recognition of dynamic facial expressions can be performed using lower spatial frequencies, decreasing the need to directly fixate on facial features.

63.4062 **Old and Young use the same visual information to identify basic facial expressions** Youna Dion-Marcoux[1,2](dioy03@uqo.ca), Hélène Forget[1], Caroline Blais[1,2], Alicia Roy-Binet[1], Daniel Fiset[1,2]; [1]Université du Québec en Outaouais, [2]Centre de recherche en neuropsychologie et en cognition.

Previous studies have shown that aging is associated with difficulties at recognizing facial expressions of fear, anger and sadness (Calder et al., 2003; West et al., 2012). Along with this alteration in performance, differences are observed between the visual scanpaths of older and younger adults during facial emotion recognition, whereby older adults fixate less on the eye area (Circelli et al., 2013). However, in emotion recognition, there is not a perfect overlap between the areas fixated on a face, and the utilization of the information contained in those areas (e.g. Blais et al., 2012 vs. Vaidya, et al., 2014). The present study therefore compared the visual information utilization of older adults (N=31; 65+ years old; Mage=71.8) to that of younger adults (N=31; 18-30 years old; Mage=22.6) during the recognition of facial emotions. The Bubbles method (Gosselin & Schyns, 2001) was used in a facial expression categorization task including four basic emotions (happy, fear, disgust and anger), displayed by either young (5 identities) or old faces (5 identities; Lindenberger, Ebner & Riediger, 2005). Classification images representing the visual information positively correlated with accuracy were separately obtained for each facial expression, facial age, and participants' age group. The results showed that older and younger participants use the same facial features in the same spatial frequency bands to accurately categorize the four basic facial expressions. Moreover, the visual information utilization was not modulated by the age of the face stimuli. Further investigation will be needed to clarify the apparent disparity between the present results, indicating no difference between old adults' and young adults' visual information utilization, and previous studies showing an altered visual scanpath in older adults.

Acknowledgement: CRSH

63.4063 **Mapping the recognition of facial expression of emotions in deafness** Junpeng Lao[1](junpeng.lao@unifr.ch), Anne-Raphaëlle Richoz[1], Chloé Stoll[2], Olivier Pascalis[2], Matthew Dye[3], Roberto Caldara[1]; [1]Department of Psychology, University of Fribourg, Fribourg, Switzerland, [2]Laboratoire de Psychologie et Neurocognition (CNRS), Université Pierre Mendès-France, Grenoble, France, [3]Rochester Institute of Technology/National Technical Institute for Deaf, Rochester, New York, USA

We are living in a world of rich dynamic multisensory sensory signals. Normal-hearing individuals rapidly integrate multimodal information for effectively decoding biologically relevant social signals, in particular from faces. However, it remains unclear how the representations of facial expression of emotions develop in the absence of the auditory sensory channel and whether they are as effective as those of hearing individuals. To this aim, we performed four psychophysical studies on observers with early-onset severe-to-profound deafness and normal-hearing controls. We first examined their ability to recognize the six basic facial expressions (anger, disgust, fear, happiness, sadness, and surprise) using (1) static and (2) dynamic stimuli. We then applied an adaptive maximum likelihood procedure to quantify (3) the intensity (using neutral-to-expression morphs) and (4) the signal levels (using noise-to-face images) required for observers to achieve expression recognition with 75% accuracy. Deaf observers showed the normal categorization profiles and confusions across expressions (e.g., confusing surprise with fear), despite requiring more intensity and signal from faces when compared to the controls. Notably, however, deaf observers showed a significantly larger advantage when decoding dynamic compared to static facial expressions, reaching a performance comparable to that of normal-hearing controls. Our data show that static visual representations for facial expression of emotions are better (de)coded in hearing compared to deaf individuals. However, this effect disappears during the more ecologically valid decoding of dynamic facial expressions, showing a critical sensitivity to motion information in the deaf population. Altogether, these findings offer novel insights into the processing of facial expression of emotions in deafness and question the conclusions obtained in this population with the use of static images only.

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Faces Perception: Social cognition 2

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Poster Session, Pavilion

63.4064 **The impact of contextual valence and self-relevance on electrocortical and behavioural responses to faces with direct and averted gaze** Sarah McCrackin[1](sdmccrac@uwaterloo.ca), Roxane Itier[1]; [1]University of Waterloo

We are rarely exposed to faces in the absence of situational context. Previous ERP research using faces primed with contextual sentences suggests that valence and self-relevance modulate electrocortical responses to faces. However, the time-course of these effects is unclear and no studies have investigated whether they interact with another key sign of self-relevance: whether the face is looking at or away from the participant. We used emotional sentences to vary the context within which neutral faces were placed. These sentences referred to the face having a positive or negative opinion (valence manipulation) of the participant or of someone else (self-relevance manipulation). Participants read each sentence before viewing the face that the sentence referred to, and faces had either direct or averted gaze (gaze manipulation). Eye-tracking was used to ensure that participants read the sentences and enforced fixation to the face, while ERPs were recorded. In a preliminary sample of 15, mean amplitude analyses of 100ms time-windows from 150-750ms after face onset were performed on a subset of occipito-temporal electrodes to track the time-course of contextual modulation. Self-relevance elicited a larger amplitude response for other versus self-relevant context on the right hemisphere, consistently from 250 to 650ms. Gaze direction interacted with valence consistently from 250 to 750ms for faces in the other-relevant, but not self-relevant context. In the other-relevant positive context, direct gaze produced a smaller amplitude response than averted gaze. In contrast, direct gaze produced a larger amplitude response than averted gaze in the other-relevant negative context. Participants also rated faces in a self-relevant context as more arousing than faces in the other-relevant context, suggesting a potential arousal-based mechanism for self-relevance effects. These results indicate that the contextual cues of self-relevance and valence impact perception of neutral faces in a complex way depending on gaze direction.

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63.4065 **Measuring the time course of spatial frequency use for face recognition from East to West** Amanda Estephan[1,2](aesthellophane@gmail.com), Camille Saumure Régimbald[1,2], Daniel Fiset[1,2], Dan Sun[3], Ye Zhang[3], Marie-Pier Plouffe-Demers[1], Caroline Blais[1,2]; [1]Department of psychoeducation and psychology, Université du Québec en Outaouais, [2]Centre de Recherche en Neuropsychologie et Cognition (CERNEC), [3]Center for Cognition and Brain Disorders, Hangzhou Normal University

Easterners allocate their attention more broadly and integrate more the peripheral elements of a scene or a face than Westerners (Boduroglu et al., 2009). Relying on the peripheral visual field entails the use of lower spatial frequencies (SF; Hilz & Cavonius, 1974). In a recent study we found that Chinese participants made a better utilization of low SF whereas Canadians made a better utilization of high SF during face identification (Tardif et al., 2015). Here, we investigate the time course of the SF utilization across cultures. For this, we used a modified version of SF Bubbles (Willenbockel et al., 2010) with 15 Canadians and 25 Chinese. The method consisted in creating temporal sequences of random SF filters, meaning that the SF available to the participant varied through time within one trial. On each trial, a randomly filtered face, either Asian or Caucasian, was presented for 300ms, followed by a robust mask. The participant had to recognize its identity among eight identities of the same ethnicity learned beforehand (block design). Multiple regression analysis on the SF sampled and the participant's accuracy was used to create group classification images showing the SF tuning across time of Westerners and Easterners for Caucasian and Asian faces separately. Statistical thresholds were found using the Stat4CI (Chauvin et al., 2005). We replicate our previous findings suggesting that Westerners make more use of higher SF than Easterners for Caucasian faces (>15.6 cycles per face (cpf); Zcrit=2.7, $p< 0.025$) whereas the latter group makes more use of lower SF than the former (from 0.3 to 12 cpf for Caucasian faces, from 0.3 to 8 cpf for Asian faces; Zcrit=-2.7, $p< 0.025$). Most importantly, we show that this cultural difference occurs within 30ms and is consistent for the next 200ms of information extraction.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

63.4066 **The impact of stress on the visual representation of an ethnic ingroup and outgroup** Andréa Deschênes[1](desa51@uqo.ca), Daniel Fiset[1,2], Hélène Forget[1], Frédérika Von Partenza Belec[1], Valiquette Joelle[1], Blais Caroline[1,2]; [1]Université du Québec en Outaouais, [2]Centre de Recherche en Neuropsychologie et Cognition

Social stress potentiates prosocial behavior (von Dawans et al., 2012) by increasing trust, trustworthiness, and sharing behavior during social interactions. Still unknown is whether this increase in prosocial behavior is also directed towards another ethnic group. We verified if a social stress altered the visual representation of an ethnic ingroup and outgroup, and if such changes were related to racial prejudices. Participants were divided into two groups and submitted to the Trier Social Stress Test for Groups (N=20) or a control condition (N=21). Participants then completed a Reverse Correlation task (Mangini & Biederman, 2004). On each trial, two stimuli were presented, composed of the same base face on which two inversely cor-

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related patches of noise were added. The participants had to decide which face looked most prototypical of a Caucasian or an African-American. All participants also completed an Implicit Association Test (Greenwald et al., 1998) to measure their level of ethnic bias. Individual classification images (CIs) were calculated by summing the noise added on the faces chosen as most representative of each ethnic group. Group CIs were then produced by summing the CIs of the eight participants with the highest (vs. eight with the lowest) level of prejudices, in each stress condition. In a second phase, 50 independent judges were asked to decide which of two CIs of the same ethnicity, coming from the same prejudice group but from different stress conditions, seemed the most trustworthy. For highly prejudiced individuals, stress made the visual representation of a Caucasian appear more trustworthy (p=0.007) whereas it was the opposite for African-American (p=0.007). This pattern of result was reversed in participants with low racial prejudices, suggesting that other mechanisms may be at play (p=0.007 and p=0.0003 for Caucasian and African-Americans, respectively).

63.4067 Are Social Categories Alone Sufficient to Elicit an In-Group Advantage in Perceptions of Within-Person Variability?

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Several studies (e.g., Bernstein et al., 2007) have demonstrated that social categorization in the absence of physical differences is sufficient to elicit recognition biases mimicking the other-race effect, thus suggesting that in-group biases alone underlie race-based deficits in face processing. If this is the case, then social categories alone should elicit an in-group advantage in another task that shows a strong benefit for own-race faces: a sorting task in which participants are asked to recognize the same identity across superficial changes (e.g., hairstyle, expression). Laurence et al. (2015) recently reported that when asked to sort images into piles representing different identities, participants sort photographs of two other-race identities into more piles than two own-race identities. In the present study, we examined whether this finding would replicate for faces that differed only in terms of social category. Caucasian participants (n = 48) were shown 40 photographs of two unfamiliar Caucasian identities (20 photographs/model) and asked to sort them into piles based on the number of identities they believed were present. Half of the participants were told that the faces were those of students currently attending their private university (a social in-group), whereas half were told that the faces were those of students currently attending a public university located out of province (a social out-group). Despite indicating that they strongly identified with their university affiliation, participants sorted the photographs into a comparable number of identities for in-group (M = 9.00, median = 8.50, range = 2-20) and out-group (M = 9.87, median = 9.50, range = 2-21) faces, p > .50, thus showing no in-group advantage in tasks examining perceptions of within-person variability. These results suggest that social categorical models of the other-race effect have limited explanatory power, as they cannot account for race-based biases in tasks outside of recognition memory.

Acknowledgement: Redeemer IRG

63.4068 Cultural differences in face processing are robust to self-construal priming

Meike Ramon[1](meike.ramon@gmail.com), Helen Roger[1], Junpeng Lao[1], Shihui Han[2], Roberto Caldara[1]; [1]Department of Psychology, University of Fribourg, Switzerland, [2]Department of Psychology, Peking University, China

Cultural neuroscience has documented numerous differences between Western Caucasian (WCs) and Eastern Asian (EAs) individuals suggesting that culture has wide-ranging effects on various basic and high-level visual and cognitive processes. For instance, WCs and EAs exhibit systematic differences in fixation patterns during the perceptual processing of faces. WC observers deploy more fixations to the eyes and the mouth, as compared to EA observers, who sample information from the nose region relatively more. Self-construal is formed by the cultural environment, with WCs and EAs identifying themselves at large as more individualistic and collectivistic, respectively. Studies of Chinese cohorts suggest that interdependent and independent self-construal priming is efficient in terms of inducing shifts in both basic visual, as well as high level processing, which can be observed at the behavioral and neural level. However, whether self-construal priming could modulate the eye movement sampling strategies during face recognition remains to be clarified. To address this question, we recorded the eye movements of WC and EA observers subsequent to inter- and independent self-construal priming, while they performed an old/new recognition task of same- and other-race faces. Self-construal priming did not determine subjects' fixation patterns during the perceptual processing of faces, with WCs and EAs persistently deploying their culturally preferred visual sampling strategies. Altogether, our data support the view that individual differences in self-construed identity cannot account for the cultural differences in face processing. More importantly, they question the idea of the individualistic and collectivistic contrast underlying the culture-dependent differences observed for perceptual face processing.

63.4069 Cross-cultural differences and similarities uderlying other-race effects for facial identity and expression

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Perceptual advantages for own-race compared to other-race faces have been demonstrated for the recognition of facial identity and expression. However, these effects have not been investigated in the same study, and to date, substantial procedural differences between the tasks used to investigate identity and expression have precluded such a comparison. To address this issue, we used a photo sorting task in which Chinese and Caucasian participants were asked to sort photographs of Chinese or Caucasian faces by identity or by expression. This paradigm matched the task demands of identity and expression recognition and avoided constrained forced-choice or verbal labelling requirements. In addition, this method can also determine the extent of cross-cultural agreement as well as differences. Other-race effects of comparable magnitude were found across the identity and expression tasks. Caucasian participants made more confusion errors for the identities and expressions of Chinese than Caucasian faces, while Chinese participants made more confusion errors for the identities and expressions of Caucasian than Chinese faces. However, analyses of the patterns of responses across groups of participants revealed a considerable amount of underlying cross-cultural agreement. These findings suggest that widely repeated claims that members of other cultures "all look the same" overstate the cultural differences.

63.4070 The Effects of Facial Dominance and Gender Prototypicality on the Gaze-cuing Effect

Troy Steiner[1](troygarrettsteiner@gmail.com), Joe Brandenburg[1], Reginald Adams, Jr.[1]; [1]The Pennsylvania State University

Social interaction is dependent upon the appropriate interpretation of others' cues. Gaze cues in particular play an essential part in social learning, cooperation, assessment of threat, and interpreting intentions. By manipulating masculinity and femininity of faces, previous research has shown that the gaze-cueing effect (i.e., the tendency for observers to respond more quickly to targets in locations cued by another's gaze compared to uncued targets) is enhanced by facial dominance cues. More gaze cuing has been reported in macaque monkeys as well, suggesting this effect is evolved and functionally adaptive. Here, we explored this effect further, using differences in appearance of naturally occurring faces. First, we presented highly archetypal faces (i.e., masculine male and feminine female faces, respectively), as rated by independent raters. Against our predictions, observers demonstrated gaze-cuing only to the female faces, not to the male faces. In a subsequent study, in order to control for gender while examining dominance, we focused just on female faces varying in high and low dominance. In this study, again contrary to our hypothesis, observers demonstrated a gaze-cuing effect only to the low dominant faces. Although we selected faces that represented gender archetypes and high/low dominance, post hoc analysis revealed that perceived prototypicality of the faces also varied between our groups in both studies, with feminine females (Study 1) and low dominant females (Study 2) being rated as the most prototypical overall. Thus, participants displayed the gaze-cuing effect to the most gender prototypical faces in both studies. In summation, our findings suggest the role of dominant facial cues in moderating reflexive gaze cuing may be oversimplified and that other socially salient cues, such as prototypically of features, may play a similar role in heightening gaze cuing effects.

Acknowledgement: NSF and NIH

63.4071 Body Perception and the Sexualized-Body-Inversion-Hypothesis

Ruth Hofrichter[1](hofricrm@mcmaster.ca), M.D. Rutherford[1]; [1]Psychology, Neuroscience & Behaviour, McMaster University

According to Bernard et al.'s (2012) Sexualized Body Inversion Hypothesis (SBIH), female bodies are viewed as objects, and processed as such by the visual system, while male bodies are processed as social objects. Their hypothesis is supported by a greater inversion effect for male than for female body images in a discrimination task. However, there are physical differences between the male and female image sets that might account for the reported differences in the inversion effect. The current study investigated how much of this sex difference can be accounted for by discriminability of images, and whether the SBIH is still supported. We replicated Bernard et al.'s study presenting participants with a target image, followed by a blank screen, then the target image presented alongside its mirror-image as a 2AFC recognition task. We found a significant Orientation by Target Sex Interaction ($F(1,47) = 9.29$, $p < 0.003$). While participants recognized upright and inverted images of females equally well ($t(46) = 1.82$, $p > 0.05$), they performed better for upright than for inverted images of males ($t(46) = 5.56$, $p < 0.0001$), consistent with Bernard et al. We conducted an ideal observer analysis to quantify the discriminability of the images, obtaining 100 thresholds for each of the 48 images (12 upright males, 12 inverted males, 12 upright females, 12 inverted females). A simple linear regression showed that discriminability predicted human performance ($t(1,46) = -2.818$, $p < 0.000$, adj. $R^2 = 0.1287$), suggesting that physical characteristics of the images account for some of the differences in the inversion effect. However, after accounting for discriminability, there was still a reliable residual difference in the inversion effects across stimulus sets as shown by a significant Target Sex by Orientation Interaction ($F(1,43) = 4.99$, $p < 0.031$), supporting the SBIH.

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63.4072 **Animacy Perception is Modulated by Stimulus Gender and Emotional Expression** Natalie Bowling[1](n.bowling@gold.ac.uk), Michael Banissy[1]; [1]Goldsmiths College, University of London

Identifying other human faces confers an important evolutionary advantage. In line with this, the ability to discriminate real human faces from artificial faces can be achieved quickly and accurately by face-processing networks. However, less is known about what stimulus qualities or inter-individual differences in the perceiver may influence whether a face is perceived as being alive. In the present study, morphed face stimuli ranging from 0-100% animate were created. The faces varied in terms of emotional expression (happy vs. neutral) and gender (male vs. female). In a threshold-setting task, participants were able to select the point on this continuum where they perceived the face to first become animate. In a series of rating tasks, participants made judgements about whether the face appeared to be 1) animate, 2) in possession of a mind, and 3) able to feel pain, at different levels along the morph continuum. Male faces were perceived to be animate at a lower threshold (i,e, closer to the inanimate end of the continuum) than female faces. They were also rated as more likely to be animate, in possession of a mind, and able to feel pain than female faces at the same animacy level. This gender difference has previously been interpreted as reflecting objectification of women's bodies; however, animacy thresholds in this study did not correlate with scores on an objectification scale. Animacy was also perceived more readily in faces with happy expressions than neutral, across both gender groups. These findings are discussed in relation to perceptual and social influences on animacy perception.

63.4073 **Investigating the influence of personal BMI on own body size perception in females using self-avatars** Anne Thaler[1,3](anne.thaler@tuebingen.mpg.de), Michael Geuss[1], Simone Mölbert[1,3,4], Katrin Giel[4], Stephan Streuber[2], Michael Black[2], Betty Mohler[1]; [1]Max Planck Institute for Biological Cybernetics, Tübingen, [2]Max Planck Institute for Intelligent Systems, Tübingen, [3]Graduate Training Centre of Neuroscience, International Max Planck Research School, University of Tübingen, [4]Department of Psychosomatic Medicine, University of Tübingen

Previous research has suggested that inaccuracies in own body size estimation can largely be explained by a known error in perceived magnitude, called contraction bias (Cornelissen, Bester, Cairns, Tovée & Cornelissen, 2015). According to this, own body size estimation is biased towards an average reference body, such that individuals with a low body mass index (BMI) should overestimate their body size and high BMI individuals should underestimate their body size. However, previous studies have mainly focused on self-body size evaluation of patients suffering from anorexia nervosa. In this study, we tested healthy females varying in BMI to investigate whether personal body size influences accuracy of body size estimation and sensitivity to weight changes, reproducing a scenario of standing in front of a full length mirror. We created personalized avatars with a 4D full-body scanning system that records participants' body geometry and texture, and altered the weight of the avatars based on a statistical body model. In two psychophysical experiments, we presented the stimuli on a stereoscopic, large-screen immersive display, and asked participants to respond to whether the body they saw was their own. Additionally, we used several questionnaires to assess participants' self-esteem, eating behavior, and their attitudes towards their body shape and weight. Our results show that participants, across the range of BMI, veridically perceived their own body size, contrary to what is suggested by the contraction bias hypothesis. Interestingly, we found that BMI influenced sensitivity to weight changes in the positive direction, such that people with higher BMIs were more willing to accept bigger bodies as their own. BMI did not influence sensitivity to weight changes in the negative direction.

63.4074 **The "threat premium" in economic bargaining and who pays the price** Shawn Geniole[1](shawn.geniole@brocku.ca), Elliott MacDonell[1], Cheryl McCormick[1,2]; [1]Department of Psychology, Brock University, [2]Centre for Neuroscience, Brock University

What information do people use when deciding to be fair or exploitative in face-to-face bargaining interactions? We show that people extract information about threat potential from a stable cue in the stranger's face, the facial width-to-height ratio (fWHR), and dynamically adjust their bargaining behaviour based on this information. In a modified Ultimatum Game, participants ($n = 100$) gave larger offers to men ($n = 48$) with larger fWHRs ($r = .46$), an effect driven by the tendency to view such men as more aggressive than those with smaller fWHRs. This "threat premium" was most pronounced for male proposers who were physically weaker, and was at odds with, and suppressed, the tendency to pay attractive individuals more than unattractive individuals. Therefore, threat potential appears to guide economic interactions involving unrelated strangers, and this effect overrides any inclinations to favour those who are more attractive.

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Object Recognition: Real world

Wednesday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4076 **Instinctive drift in the illusory perception of objects: The ready perception of animate objects in random noise** Joshua New[1](jnew@barnard.edu), Sarah Lazarsfeld[1], Mary Seo[1], Melyssa Luxenberg[1]; [1]Barnard College, Columbia University

Pareidolias are the illusory perception of meaningful objects – often faces – in random, unpatterned stimuli. We evaluated the hypothesis that a biological preparedness for detecting animate objects (people and animals) makes their illusory experience especially likely and explored which manners of visual noise and features might contribute to their occurrence. In Experiment I, participants were asked to trace and label any objects appearing in unchanging or slowly changing displays of Perlin noise – a gradient noise which approximates the natural phenomena in which pareidolias are commonly experienced (e.g. clouds). Nearly half of the pareidolias reported were of people, followed in frequency by animals, then artifacts, then plants and other inanimate objects. Pareidolias were reported as frequently in unchanging noise as they were in slowly changing noise. In Experiment II, slowly changing Perlin noise was again particularly evocative of pareidolias of people and somewhat of animals – whereas displays filled with slowly changing Gaussian or uniform noise were more likely to provoke pareidolias of inanimate objects. In Experiment III, participants experienced more illusory objects when many small curvilinear, or rectilinear segments, or both, were embedded in slowly changing Gaussian noise. Even in Gaussian noise, animals were reported most often, driven largely by their frequent perception amongst curvilinear segments. These preliminary studies 1) confirm that neurologically-typical individuals will readily and illusorily experience complex and meaningful objects in random noise, 2) suggest that animate objects are especially likely to be illusorily perceived and 3) constitute a novel approach for uncovering the fundamental visual features (i.e. curvilinearity) involved in the perception of animate objects and perhaps of other natural categories.

63.4077 **Contextual Facilitation of Action-related Object Pairs** Ruosi Wang[1](ruosiwang@fas.harvard.edu), Yaoda Xu[1]; [1]Harvard University

Objects rarely appear in isolation, instead, they often appear in pairs in which a meaningful action may be performed between them, such as a pitcher and a cup. Indeed, previous behavioral studies have demonstrated that positioning action-related object pairs in familiar action colocations facilitate recognition in contrast to unfamiliar colocation. And such benefit only appears in contextually congruent but not contextually incongruent pairs. In the current study, we manipulated contextual congruency, colocation, and the action state of one of the objects in the pair. For the congruency manipulation, a pair of objects could be either contextually congruent (e.g. a pitcher and a cup) or incongruent (e.g. a pitcher and a nail). For the colocation manipulation, a pair of objects could appear either in a familiar action colocation (e.g. a pitcher pointed towards a cup), an unfamiliar action colocation (a pitcher pointed away from a cup), and a nonaction colocation (a pitcher and a cup appeared side by side). For the action state manipulation, in some of the object pairs, the action-conducting object could be either active (e.g. a pair of opened scissors) or inactive (e.g. a pair of closed scissors). Behavioral response time on judging whether two objects go together was collected. Preliminary results showed faster judgment time for congruent pairs in familiar action colocations than both congruent pairs in unfamiliar action colocations and nonaction colocations. Additionally, active objects facilitated judgment more than inactive ones. These results replicated and extended previous behavioral findings, suggesting possibly stronger integration between the congruent objects in familiar action colocations. Using fMRI multi-voxel pattern analysis, we will next examine where in the ventral and dorsal visual processing.

63.4078 **Psychophysics of Fingerprint Identification** Parker Banks[1](banksp@mcmaster.ca), Patrick Bennett[1], Allison Sekuler[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Despite popular misconceptions, crime-scene fingerprint identification is not an automated process. Instead, human examiners must visually match latent fingerprints collected from crime scenes to references from potential suspects. Past research has indicated an effect of source finger type on accuracy when identifying fingerprints. However, it is unknown whether this effect is due to differences in the information each digit provides, or how that information is processed. Therefore we conducted an experiment to investigate the influence of source finger type, image similarity, and level of available stimulus information on response accuracy in a same-different task that required naive subjects to indicate whether pairs of latent and reference fingerprints matched. Latent fingerprints were processed using principle component analysis to vary the amount of stimulus information, that is, the percentage of variance explained in each image when compared to the fingerprint eigenspace. To determine the effect of image similarity, non-matching reference prints were of either low or high cosine similarity to latents. Our findings replicated those of previous studies, demonstrating that identification accuracy depends on source finger type and image similarity, and that no digit/similarity interaction was present. Higher accuracy was associated with the thumb, middle digit, and dissimilar images, while that for the little finger was lower. Signal detection analyses revealed a positive linear relationship between identification accuracy and the percentage of variance accounted for in latent prints. We also found an overall negative relationship between accuracy and response time, and that the accuracy/RT relation depends on the source digit and amount of stimulus information. Currently we are conducting experiments examining the effects of image quality on response accuracy. However, preliminary evidence suggests that the effect of digit on accuracy is due to differences in how fingerprints are processed, rather than the information each digit provides.

Acknowledgement: NSERC

63.4079 **Exploring the Real Object Advantage in Recognition Memory using fMRI** Michael Compton[1](mcompton@unr.edu), Edward O'Neil[2], Lars Strother[1], Jacqueline Snow[1]; [1]The University of Nevada, Reno, [2]University of Toronto

There is accruing evidence that suggests real objects are visually processed and represented differently as compared to matched planar image displays. Recent behavioral studies have shown that real objects are more memorable than images – a phenomenon we refer to as the 'real object memory advantage'. We used event-related fMRI to examine whether or not the real object advantage is attributable to the recruitment of ventral stream object-selective areas during recognition memory. Participants completed a study phase in which they were presented with a large set of everyday objects. Critically, half of the stimuli were presented as real-world objects and the remainder as high-resolution color images. The images were matched closely to their real-world counterparts for size, viewpoint, and illumination. Two hours later, participants completed a two-AFC recognition task in an fMRI scanner. At test, the stimuli were displayed as words to ensure that behavioral and brain-based differences were not attributable to congruence in display format between study and test. Behaviorally, recognition performance for stimuli encoded as real objects was superior to those encoded as images, replicating our earlier result. Surprisingly, our preliminary fMRI analyses did not reveal any compelling evidence of neural correlates of the real object advantage in the ventral visual object recognition system, which was presumably engaged during encoding. Rather, the neural basis of the real object memory advantage appears to reside in dorsal (i.e., fronto-parietal) and anterior ventral regions of cortex. In summary, our behavioral data replicate and extend previous findings, and our neuroimaging data reveal a previously undiscovered neural basis of the real object memory advantage.

63.4080 **Real-world size improves recognition of real objects, not images.** Desiree Holler-Kidder[1](DesireeHoller@gmail.com), Jacqueline Snow[1]; [1]The University Of Nevada, Reno

Patients with visual agnosia can show improved recognition for real-world objects – a phenomenon known as the 'Real Object Advantage'. Although some have argued that this phenomenon is attributable to additional stereo cues present in real objects (but not planar images), an intrinsic feature of most real objects is that retinal size corresponds to the object's physical size. Conversely, the size of an object as represented in a two-dimensional image does not convey definite physical size cues. Here we investigated whether expectations about real world size influence object recognition. We studied recognition performance in a patient with bilateral LOC lesions and profound visual form agnosia, and a group of neurologically healthy observers. The stimuli were 3D-printed common objects, whose physical size either corresponded with real world size, or was scaled 50% smaller, or 50% larger, than the object's normal size. Recognition performance was contrasted for the real objects versus images of the same items matched closely for size, viewpoint, and illumination. In both the patient, and healthy observers, recognition was superior for normally-sized real objects, versus the scaled objects. Conversely, for images displays, the size manipulation did not influence recognition performance. Our data demonstrate that the 'Real Object Advantage' is a recognition phenomenon not limited to cases of visual agnosia, and that physical size is an integral component of normal mental object representations.

63.4081 **Photographs elicit more associations than highly recognizable color or outline drawings** Anne Gilman[1](anne.gilman@gmail.com), Anh Le[1], Caitlin McCann[1], Ankara Shepard[1], Kiera Foster[1], Melina Olivas[1]; [1]Psychology Department, Juniata College

Research suggests that visual working memory is sensitive to the semantic richness or meaningfulness of the stimuli used (see Brady, Konkle, & Alvarez, 2011). Differences in meaningfulness are often treated as categorical by contrasting abstract shapes with images of real-world objects. Can we instead quantify image meaningfulness? Gilman, Ware, & Limber (2010) asked participants to list associations that came to mind when viewing images from earlier working memory trials and found that color photos elicited significantly more and more-varied associations than grayscale drawings. Colorful shapes showed a similar advantage compared to grayscale shapes. Their stimuli were not assessed for recognizability, which could influence the retrieval of meaningful associations. The present study contrasted well-tested images of real-world objects for associational differences. Two image sets were created, each containing 22 color photos of big and small objects (Konkle & Oliva, 2012), 10 color drawings (Rossion & Pourtois, 2004), and 10 partial line drawings (Hayworth & Biederman, 2006). Objects featured in a color drawing in the first set were featured as line drawings in the second and vice versa. Following training, 41 participants named each image and provided their image-recognition confidence and related associations. Photos elicited the most associations (M=3.61), followed by color drawings (M=3.55) and line drawings (M=3.45); this difference was signficant, $F(2,1666)=6.136$, $p< .01$. Surprisingly, higher recognizability was weakly but significantly correlated with fewer associations provided, with the greatest effect ($r=-.15$, $p< .01$) for line drawings, the most variable image type (M=87, sd=18 versus M=95, sd=12 for color photos and drawings). These participants had no time restrictions, unlike Gilman, Ware, & Limber's (2010), and provided narrative associations not obtained in the earlier precedent. Despite the puzzling negative correlation between recognizability and associations offered, our results support using associations for quantifying image meaningfulness, preferably with specific requests for words evoked by the image rather than general associations.

63.4082 **Pre-verbal infants automatically activate real-world object size information** Bria Long[1](brialong@fas.harvard.edu), Susan Carey[1], Talia Konkle[1]; [1]Department of Psychology, Harvard University

When adults recognize an object, they automatically activate real-world size information: in the familiar-size Stroop effect, adults are faster to detect if an item is bigger on the screen when they know it is bigger in the world (Konkle & Oliva, 2012). Here we examined whether this phenomenon also occurs in pre-verbal infants, who have had significantly less experience with objects and who do not even know the words "big" and "small." To do so, we used a natural-preference procedure: 13-month-olds viewed two objects on either side of fixation while a Tobii T60 monitored their eye position. Critically, the visual size of objects was either congruent (e.g., a big car and a small shoe) or incongruent (e.g., a big shoe and a small car) with their familiar size in the world. Infants viewed displays for a maximum of 10s (Exp1) or 30s (Exp2) or until they looked away for

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a cumulative (Exp1) or consecutive (Exp2) total of 2s. Across both experiments, we found that infants preferred to look at the object that was visually bigger on the screen; however, this effect was significantly reduced on incongruent displays (E1: Mdiff=.059, SDdiff=.12, t(15)=1.94 p=.036, one-tailed; E2: Mdiff=.044, SDdiff=.089, t(15)=1.99 p=.032, one-tailed). Specifically, though infants first looked at the visually bigger object on both kinds of displays, on incongruent displays infants gradually spent more time looking at the object that is typically bigger in the world, even though it was visually smaller on the screen. In other words, infants naturally preferred to look at both visually big and typically big objects. Thus, pre-verbal infants were sensitive to the congruence between visual size and real-world size. While this automatic association could have taken years to develop, these results suggest that real-world size information is incorporated into infants' early-emerging object representations.

63.4083 Body emotion recognition depends on vertical orientation subbands during middle childhood Jamie Schmidt[1,2](jamie.schmidt.2@ndsu.edu), Amanda Auen[1], Benjamin Balas[1,2]; [1]Department of Psychology, College of Math and Science, North Dakota State University, [2]Center for Visual and Cognitive Neuroscience, North Dakota State University

Distinct orientation subbands (like spatial frequency subbands) make differential contributions to facial recognition and emotion identification in faces. In particular, horizontal orientation subbands are essential for facial emotion recognition in adults and child observers (5-10 years of age). In prior work, however, we have shown that emotion recognition from body images depends on different orientation information: Adults recognize emotion more effectively from body images containing vertical orientation energy. Given that we have also found that the tuning of facial emotion recognition to diagnostic and non-diagnostic subbands changes during middle childhood, we chose to investigate children's sensitivity to diagnostic orientation subbands for body emotion recognition. We recruited 30 children (5-10 years old) to perform a simple emotion categorization task using body images with the horizontal or vertical orientation energy information filtered out. We compared younger children's performance (5-7 years) to older children (8-10 years) to determine how the use of vertical vs. horizontal subbands differed with age. Our older group of children performed better at the task in general ($p< 0.001$), but both age groups exhibited poorer sensitivity to happy vs. sad emotion in the horizontal condition (Mean $d' = 1.63$) versus the vertical ($M = 2.40$) and both subband ($M=2.41$) conditions ($p < 0.001$), and we observed no interaction between filter orientation and age group. Likewise all participants were slower at the task when given only horizontal information relative to the other two conditions ($p< 0.001$), suggesting that the sensitivity results do not simply reflect a speed-accuracy trade-off. We propose, based on these results, that an adult-like bias favoring vertical orientation energy for body emotion recognition is present during early childhood. Also, compared to our prior work describing children's abilities to recognize emotion in filtered face images, young children appear to be better able to recognize body emotion using non-preferred orientation information.

Acknowledgement: NSF1348627

63.4084 Increased willingness-to-pay for real foods versus image displays. Carissa Romero[1](carissaromero7@live.com), Nicole Haddad[1], Jacqueline Snow[1]; [1]The University of Nevada, Reno

Understanding the factors that drive healthy vs. unhealthy food choices, and caloric intake, are central to curbing rising rates of obesity. In everyday life food choices are most often made when consumers are confronted with real foods (e.g., at the cafeteria or supermarket), yet previous studies have focused predominantly on food choice behavior towards, and estimates of caloric content of, planar image displays. Importantly, however, unlike images real foods can be physically consumed and they have an actual (rather than inferred) caloric content. Here, extending a recent study in the domain of economics, we examined whether observers were willing to pay more for snack foods presented as real objects versus planar images, in the context of a Becker-DeGroot auction. We also examined whether caloric density, and 'healthiness', influenced willingness-to-pay. Critically, we used a within-subjects design to ensure that variations in bids were not attributable to between-group differences, and trials in the different display conditions were interleaved randomly throughout the testing session. We also used identical display sequences and procedures in the real-food and image conditions, and our stimuli were matched closely for size, viewpoint, and illumination. Under these controlled viewing conditions, observers' willingness-to-pay for snacks increased by 9.35% when they were presented with the real items versus matched image displays. Further, after controlling for a-priori likingness, the true caloric density of the foods predicted how much participants were willing to pay for real foods, but not for foods displayed as images. These results suggest that the overall reward value of healthy and unhealthy foods, and the influence of caloric content on valuation, depend critically on the food being physically present at the time of choice.

63.4085 Observers misperceive the size of artificial limbs Ritika Mazumder[1](mazrm-17@rhodes.edu), Jason Haberman[1]; [1]Rhodes College

In creating a prosthetic device for lower-limb amputees, prosthetists report purposely making the limb smaller along the width dimension than the corresponding intact limb. This is in response to the patients' report that the limb appears too 'bulky' if exactly matched in size to the intact limb. These experiments investigated the veracity of this perceptual bias. We first verified that prosthetists do, in fact, make prostheses smaller than the corresponding intact limb by comparing the size of both in a set of 35 images depicting patients wearing artificial limbs. The results revealed that prosthetists make the artificial limbs on average three percent smaller than the intact limb. Next, we explored whether observers exhibited a perceptual bias in perceiving prostheses viewed in the context of a body. Participants adjusted the width of the prosthesis in the same set of images (both upright and inverted) until it looked 'right.' Unexpectedly, observers adjusted the prosthetic limbs to be larger that the intact limbs by about seven percent, suggesting they perceived it to be smaller than the intact limb. Although the bias persisted when the images were inverted, it was significantly reduced, suggesting configural processing enhanced the size misperception. In a separate control experiment, when observers were instructed to adjust the size of the intact limb, the size bias was significantly mitigated. Further, when observers adjusted the prosthetic limb without the context of a body (i.e., only the prosthetic and intact limbs were visible), the size bias was again greatly reduced. Overall, the results suggest that observers underestimated the size of a prosthetic device, and this was most evident in the context of whole, upright bodies. However, the direction of this bias is unexpected given the clinical standard. It remains to be seen whether amputees exhibit a similar perceptual bias under formal testing conditions.

63.4086 Substance over style? The role of high and low level visual properties in novice impressions of artistic style Caitlin Mullin[1](caitlin.mullin@ppw.kuleuven.be), Rebecca Chamberlain[1], Sander Bisselink[2], Johan Wagemans[1]; [1]University of Leuven (KU Leuven), [2]Radboud University Nijmegen

Style is a multidimensional attribute of an artwork. While art historians may categorize artworks based on high-level concepts, such as the historical period, this level of description may not align with low-level visual properties of style that are extracted by the visual system. Here, we attempt to reveal the relevant dimensions of style by asking which visual features determine how participants categorize artworks. Using a natural grouping task, participants were asked to hierarchically sort artworks from eight artistic periods into eight groups based on the criteria of their choice. They were then asked to provide labels for each sub-group they created. Results of a thematic analysis revealed that participants primarily sorted on high-level concepts such as semantic image content (e.g. people) and broad style themes (e.g. modern) while lower level-visual features such as colour and texture were used only at lower hierarchical levels. In addition, we conducted multidimensional scaling analysis (MDS) to quantitatively determine which features participants used to categorize the paintings. The results mirrored that of the thematic analysis with the most relevant dimension separating the paintings by broad high-level elements such as historical period (old-new). In an attempt to maximize the contribution of lower-level stylistic elements, we repeated the same experiment preventing participants from relying on semantic content as a categorical dimension. As expected, results of the thematic analysis showed participants relying more heavily on colour and image structure at the first level of grouping, although the MDS showed no clear single dimension emerging from the analysis. These findings are in line with previous work (Augustin & Leder, 2006; Wallraven et al., 2009) emphasizing the high-level processing that the average observer makes when viewing artworks, forming meaningful and consistent categories. However, these consistencies are largely based on image content rather than low-level visual characteristics.

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63.4087 Human tilt estimation in local patches with natural stereo-images Seha Kim[1](sehakim@sas.upenn.edu), Johannes Burge[1]; [1]Department of Psychology, University of Pennsylvania

Estimating 3D surface orientation (i.e. slant and tilt) is an important first step toward estimating 3D shape. To understand how different image cues are combined for surface orientation estimation, we examine human estimation of tilt in stereo-images of natural scenes. First, we built a custom display system with a stereo-enabled Vpixx ProPixx projector and a Harkness Clarus 140 polarization-maintaining screen. Next, we obtained a large database of stereo-images of natural scenes with precisely co-registered range data. These stereo-images provide rich cues that influence surface orientation perception; the range data provides the ground-truth tilt, slant, and distance at each pixel. We binned the range data according to local tilt, slant, and distance and randomly sampled corresponding 1deg image patches within each bin. Then, we assessed human tilt estimation using these patches. Human observers sat 3m from the screen such that the left and right retinal images were identical to the images that would have been formed by the original scene. On each trial, observers binocularly viewed a patch of scene through a 1deg aperture. The task was to estimate tilt of the depicted surface using a mouse-controlled probe. We compared human estimates of tilt to ground-truth tilt computed directly from the range data. A rich set of results emerged. First, human tilt estimation was generally accurate but was biased towards the cardinal tilts (i.e. 0, 90, 180deg: tilts of surfaces slanted about vertical and horizontal axes). Second, tilt estimation error varied systematically with ground-truth tilt: errors at the cardinal tilts were lower than at other tilts. Third, the pattern of human biases and errors matched the performance of a previously developed ideal observer for 3D surface tilt estimation in natural scenes (Burge & Geisler, 2015). Thus, our preliminary findings suggest human observers may optimally process local cues to 3D surface orientation.

Object Recognition: Reading

Wednesday, May 18, 8:30 am - 12:30 pm
Poster Session, Pavilion

63.4088 Perceptual Grouping Influences Mental Arithmetic Performance

Patrick Garrigan[1](pgarriga@sju.edu); [1]Department of Psychology, Saint Joseph's University

Arithmetic expressions involving more than one operation (e.g., 3 + 4 x 2) should be evaluated in agreement with the rules of operator precedence (i.e., the "order of operations"). Besides explicit knowledge, well-practiced observers exploit perceptual processes like unit formation and attention to ensure these rules are followed. This can be demonstrated by putting the principles of perceptual organization into competition with operator precedence. E.g., using grouping by proximity, if the numbers around an addition are closely spaced and the numbers around a multiplication are widely spaced - i.e., perceptual grouping by spacing is inconsistent with the order of operations - error rates increase. Here we consider "mental arithmetic", which is believed to operate through verbal representations. If visuospatial information is lost in verbal recoding, error rates in mental arithmetic should be independent of perceptual organization (inconsistent or consistent with the order of operations). In a series of experiments we examined grouping effects by proximity in mental arithmetic. Using expressions with spacing that was either consistent or inconsistent with operator precedence, participants (1) evaluated briefly presented expressions that were then visually masked or (2) verbalized expressions prior to evaluating them. Both manipulations were intended to promote verbal recoding. In all cases, however, grouping effects persisted, indicating that the representations associated with mental arithmetic retain visuospatial characteristics. Analysis of errors by type revealed that perceptual grouping of numbers and operators by proximity influences operator precedence in all conditions studied, and the identification of operators when visual encoding time is limited. These results suggest that the representations on which mental arithmetic operate are not purely verbal, illustrate an interesting and novel case of visual cue integration, and underscore the importance of perceptual learning in basic mathematics instruction.

63.4089 Crowded Letter Recognition in Peripheral Vision Is Not Solely Determined by Target-Flanker Cortical Distance

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Letter recognition and reading in peripheral vision is limited by crowding. It has been proposed that the spatial extent of crowding corresponds to a fixed distance on primary visual cortex (Pelli, Current Opinion in Neurobiology, 2008). Hypothetically, if peripheral letter recognition is only determined by crowding, then same target-flanker cortical distance will yield the same performance, regardless of other factors such as eccentricity or letter size. To test this idea, we re-analyzed the data from Legge, Mansfield & Chung (Vision Research, 2001), where triplets of letters were shown at different locations on a horizontal line to measure recognition ability. This measurement was performed at different vertical eccentricities, from 0° (central field) to 20° (lower field) with acuity-compensated print sizes. In the original work, the accuracy-vs-letter-position visual-span curves were bell-shaped, peaking at the vertical midline. As the vertical eccentricity increased, the curves became narrower and lower. Here, we have estimated the cortical distance between a target letter and its neighboring letter using target eccentricity, center-to-center letter spacing, and cortical magnification factor (Horton & Hoyt, Arch. Ophthalmol., 1991). Unlike our initial hypotheses, we found that cortical distance alone cannot account for our letter recognition performance. When target-flanker cortical distance is equated, recognition performance worsens as the target letter eccentricity increases. Surprisingly, when we further compute the ratio of cortical distance over target letter eccentricity, we found that recognition performance only depends on this ratio. Our findings here show that if crowding is determined by cortical distance alone, it does not entirely account for flanked letter recognition performance in peripheral vision. Some other property of visual processing also plays a role, one that reduces recognition performance with eccentricity. Identifying this visual function will help us better understand what limits letter recognition and reading in peripheral vision, and how to improve peripheral reading.

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63.4090 Crowding and grouping in letter recognition

Deyue Yu[1](yu.858@osu.edu); [1]College of Optometry, Ohio State University

Crowding can increase or decrease with additional flankers, depending on the grouping among stimulus components. Here, we examined how letter crowding changes with increasing number of flanking letters, and whether the change is modulated by letter complexity. In the experiment, stimuli were letter strings constructed using lowercase Courier font with a print size of 1° and a spacing of 1.16 × x-width. Identification accuracy was measured for the middle target letter which was flanked by either two or four flankers and presented at 10° to the left or right of fixation. Flankers were always duplicate letters, and either identical to or different from the target letter. There were a total of 676 target-flanker combinations plus 26 isolated letters. Identification accuracy was nearly perfect (0.98) for isolated letters. When increasing the number of flankers from two to four, no change in performance (0.68 vs. 0.75) was observed for identical target-flanker condition. For the non-identical condition, identification accuracy was lower for pentagrams (0.44) than for trigrams (0.55). Analysis of the error trials revealed that the deterioration resides in mislocation rather than crowding. There were more mislocation errors in pentagrams (0.24) than in trigrams (0.16). Linear regressions were performed to assess the effect of letter complexity. We found that higher flanker complexity led to worse performance while higher-complexity targets made identification easier. Specifically, more complex flankers induced greater crowding and more mislocation errors. Higher target complexity was associated with lower mislocation rates, and corresponded to less increase or even reduction in mislocation errors when doubling flankers. Our findings demonstrate that the letter crowding or the effect of grouping among stimulus components does not change with number of flankers. However, additional flankers do lead to more letter substitution, which is modulated by target letter complexity.

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63.4091 Dissociation between magnocellular and parvocellular processing in visual word recognition

Théodora Vahine[1], Stéphanie Mathey[1], Jean-Noël Foulin[1], Sandrine Delord[1]; [1]Laboratoire de Psychologie (EA 4139), Université de Bordeaux, France

The objective was to test whether the parvocellular/magnocellular (P/M) dissociation found for visual objects also holds for word materials using the orthographic neighborhood (ON) effect in two lexical decision task experiments. Hermit words (i.e., with no ON) would have faster access to the lexicon than words with ON (i.e., word –acteur– with one higher frequency orthographic neighbor –auteur). In such letter substitution neighborhood, letter identity should be the critical dimension, conveyed by the P system. Spatial frequency (SF) filtering of the target (Experiment 1) and isoluminant stimuli (Experiment 2) were used to bias visual processing toward P (medium to high SF filtering or isoluminant colors) or M system (low SF filtered or grey low contrast). Experiment 1 results replicated the main inhibitory effect of ON on lexical decision latencies. A main effect of filtering was also observed, with shorter response times (RTs) for non-filtered control words, longer RTs for band-passed filtered words, and even longer RTs for low-passed filtered words. However, these two factors did not interact. Experiment 2 results replicated the main inhibitory effect of ON, and a main effect of isoluminant condition was found with longer RTs for the isoluminant words than for the low contrast grey words. Furthermore, an interaction between ON and isoluminant conditions was observed, with the ON effect found in the isoluminant condition only. Taken together, these results are consistent with the hypothesis of dissociation between the two visual systems for orthographic activation in visual word recognition processes. When letter identity is the relevant information, lexical access depends mainly on P visual processing. Comparison between the experiments also shows that isoluminant stimuli should provide a better P/M dissociation than SF filtering.

63.4092 Binocular integration across the visual field for letter recognition in normal and glaucomatous vision

Lillian Chien[1](lchien@uab.edu), Rong Liu[1], Christopher Girkin[1], MiYoung Kwon[1]; [1]Department of Ophthalmology, School of Medicine, University of Alabama at Birmingham

Glaucomatous visual field loss often comes asymmetrically between two eyes. As clinical tests of vision loss are usually performed on each eye separately, a way of predicting the binocular visual field from monocular visual fields is useful. While previous studies tested binocular integration models using light sensitivity (Nelson-Quigg et al., 2000), it remains unclear how this combination affects everyday visual tasks, such as reading. The purpose of this study is to determine the best model for predicting binocular visual field integration for letter recognition, the building blocks for reading. The binocular summation properties were tested by comparing contrast thresholds for letter recognition under three viewing conditions: monocular viewing with either eye, and binocular viewing. Subjects, with glaucoma or normal vision, identified alphabet letters at thirteen predetermined locations across the visual field subtending 25 degrees visual angle. The target letter was presented at an intended retina location using a gaze-contingent display paradigm. Using monocular data, the binocular visual field sensitivity was predicted using three models: i) Best Eye; ii) Best Location, using the location with highest sensitivity for each eye; and iii) Quadratic Summation. The differences (Mean Squared Errors) between predicted and actual binocular fields were calculated to evaluate the best model. Our results showed that, for normal vision, Quadratic Summation best describes the binocular summation property of letter recognition in both the fovea and the periphery. Similarly, for glaucomatous vision, in unaffected retinal locations, Quadratic Summation (MSE=8.02) is superior to Best Eye (MSE=20.50) and Best Location (MSE=17.60). However, in affected retinal locations, Best Eye (MSE=3.28) or Best Location (MSE=3.38) is more accurate than Quadratic Summation (MSE=5.32). Our results suggest a dual-approach to binocular visual field integration for glaucomatous vision. Our findings further suggest that this dual-approach may be useful for understanding everyday binocular function, such as reading, in glaucoma patients.

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63.4093 Age-related changes in the visual span, crowding and reading speed

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Evidence showed that the developmental changes of the size of the visual span (the number of letters that can be recognized at one glance) and crowding (the inability to recognize objects in clutter) are linked to the developmental changes in reading speed (Kwon et al. 2007). However, little is known about age-related changes in the visual span and crowding and their relationships with age-related changes in reading speed. To address these questions, the visual span, crowding, and reading speed were measured in both young (mean age 24.2±3.6, n=10) and older adults (mean age 57.9±7.7, n=10) with normal vision. Visual-span profiles were measured by asking subjects to recognize letters in trigrams (strings of random three letters) flashed briefly at varying letter positions left and right of the fixation point. The size of the visual span was defined as the area under the profile, a plot of recognition accuracy as a function of letter position. Crowding was measured by asking subjects to recognize a target letter presented with flankers, at four eccentricities. Crowding zone was defined as the distance between the target and flankers required to yield 79.4% accuracy. Reading speed was measured with short blocks of text. Older adults showed significantly slower reading speed (by 25%, p=0.02) than young adults. While no noticeable decrease was found in single-letter recognition (p=0.60), older adults exhibited considerable impairment in crowded-letter recognition: significantly smaller visual span (by 18%, p< 0.01) and larger crowding zone (by 37%, p< 0.01). Both visual span (r=0.55, p=0.01) and crowding zone (r=−0.57, p< 0.01) were correlated with reading speed. Our results showed that, even in the early stage of aging, there were significant changes in the visual span and crowding. Our findings suggest that age-related decline in the ability to recognize targets in clutter may in part explain slower reading in older adults.

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63.4094 Reduction in Legibility with Degradation in Older and Younger Observers

Benjamin Wolfe[1](bwolfe@mit.edu), Jonathan Dobres[1], Anna Kosovicheva[2], Ruth Rosenholtz[3], Bryan Reimer[1]; [1]AgeLab, Massachusetts Institute of Technology, [2]Department of Psychology, Northeastern University, [3]CSAIL, Massachusetts Institute of Technology

Previous work examining the impact of a set of intrinsic and extrinsic features on relative legibility of typefaces has shown that legibility losses are more pronounced in older subjects (Dobres et.al, VSS 2014). To better understand the effects of visual degradation on legibility for older and younger subjects, we performed an experiment in which two groups of subjects (20-29 and 60-69 years old) were asked to perform a lexical decision task, determining whether a briefly presented stimulus (250 ms) was a word or non-word. All stimuli were generated in the typeface Frutiger, known from our previous work to be an easily-read typeface. To simulate the loss of sensitivity to high spatial frequencies (Elliott et.al, 1990) and the increase in intrinsic noise (Bennett et.al, 2007) both of which are realities for the aging visual system, we degraded our stimuli, on separate trials, by applying either Gaussian blur, or 1/f noise at a range of levels. For each subject, we estimated 75% performance thresholds by fitting accuracy at each level to separate psychometric functions for the blur and noise conditions. We find significantly higher thresholds in the 60-69 age group compared to the 20-29 age group in both the blur and noise conditions, suggesting that our older subjects' performance was more affected by small reductions in legibility. At a more granular level, we find significant reductions in performance at low levels of distortion in older subjects, but similar maximum levels of performance in both groups without distortion. Together, these results suggest that legibility is profoundly impacted by small manipulations or degradations of the letterforms, particularly for older subjects, and that accounting for this sensitivity is essential to facilitate legibility of written material across the age span.

63.4095 Effects of Length of Reading Materials on Key Parameters of Reading Speed Function

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Purpose: Reading evaluation has been gradually accepted as a clinically important vision test in low vision rehabilitation. There are several versions and reading materials varies from unrelated random words to a paragraph of text (approx. 130 words). Purpose of this paper is to investigate into the effect of length of reading materials on two key parameters, location of reading function(LRF) which is closely related to critical print size(CPS) and maximum reading speed(MRS). Methods: In one experiment, reading materials were both 4-character clauses and 30-character sentences in Japanese. In the other experiment, they were random combinations of a Kanji and a Kana, 4-character clauses, and 10-character short sentences. In an experimental session, one type of reading material was tested. Different reading content was presented in each trial and participants were asked to read aloud as quickly and precisely as possible. A session started with the largest character size of 61.93 min of arc and proceeded to 0.1 log smaller trials until no single character was read. Reading time and errors were recorded and reading speed function was plotted for each reading material condition. Two parameters were estimated using Weibull fitting. Thirty three Japanese for one experiment and 28 for the other participated and all had corrected/uncorrected normal visual acuity. Results and Discussion: Combining results of two experiments, there was a moderately good agreement in LRF estimates among different reading material conditions with 0.5 through 0.7 correlations. As for MRS, there was a very systematic increase along with the length of reading material. We conducted a mixed effect model analysis on MRS data with a model, reading time (msec) = latency + unit reading time (msec/char) x character length. The model fit well (R2=0.99). We conclude that these findings help us compare and convert results of different reading evaluations.

63.4096 Effects of Luminance Contrast and Character Size on Reading Function.

Madoka Ohnishi[1](g07c022@gmail.com), Terumi Otsukuni[1], Aoi Takahashi[1], Michiko Sugiyama[1], Mako Hirakimoto[1], Sachie Kawamura[2], Atsuo Suzuki[2], Yuta Oshima[2], Koichi Oda[1]; [1]Tokyo Woman's Christian University, [2]Kyodo Printing Co., Ltd.

Reading is tolerant to contrast reduction, but its rate decreases when character size becomes quite large or small (Legge et al., 1987). This study re-examines the relation between letter contrast and reading function for a broad range of luminance contrast. We measured the reading speed for single Japanese clauses comprising two-letter Kanji and two-letter Kana words in various sizes and luminance contrast levels. Reading rate (char/min) was calculated from the reading time for each clause. The largest clause was displayed in the first trial, and character size decreased by 0.1 log step until participants could not read any letter. The letter size was ranged from 3.10 to 123.86 arc min. The participants were 9 young and 20 older Japanese people with normal vision. Reading speed function of character size was plotted and three parameters—maximum reading speed (MRS), shape of the function, and the location of reading function (LRF)—were estimated for each contrast using Weibull fitting. While MRS and the shape of the functions remained unchanged, LRF systematically varied according to stimulus contrast, which agrees with the finding of Fujita et al. (2008). The relation of LRF and contrast were linear in log-log scale (LRF(log) = a + contrast(log) * b). Regression analysis indicated that participants' visual acuity had a statistically significant effect on its interception. Our results revealed similar but stronger tolerance of reading performance for a wide range of contrasts. The systematic dependence of LRF on luminance contrast reflects the relation of the critical spatial frequency for reading (Legge et al., 1985) and human CSF. With decreasing stimulus contrast, spatial frequency available to observers becomes lower but low frequency channels allow fluent reading.

63.4097 **Vertical and Horizontal Arrangements of Chinese Characters** Lin SHI[1,2,*](lin.shi@live.cn), Yue ZHANG[3]; [1]Faculty of Information Engineering and Automation, Kunming University of Science and Technology, China, [2]Yunnan Provincial Computer Application Key Laboratory, China, [3]Faculty of Mechanical and Electrical Engineering, Kunming University of Science and Technology, China

Vertical and horizontal arrangements of English, Chinese, and other languages showed different characteristics of reading in many aspects including eye movements, reading speed, and optimal viewing positions. Here, we were interested in the visual aesthetics of vertical and horizontal arrangements of Chinese characters. Inside a chamber room, a 27-inch LCD monitor was masked by a square dark board with a square window. The size of the Chinese character image on the screen was 2 visual degrees. The Chinese character images were created from the stone inscription sets handwritten by Zhenqing YAN in the Tang Dynasty, who was one of the greatest calligrapher in Chinese history. An arrangement consisted of 7 images, which were arranged initially at random positions near the central vertical or horizontal line on a grey square background sized 17 visual degrees. Twenty participants were asked to make aesthetic arrangements of the Chinese character images in the horizontal or vertical direction using drag-and-drop operations controlled by the mouse. Thirty vertical arrangements and thirty horizontal arrangements were included alternately in each participant's experiment. After the arrangements of all participants, evaluations were given by them with values ranging from 1 to 10, and high values indicated better visual aesthetic of arrangements. The participants' eye movements and operations were both recorded in the experiment. Results showed that, (1) the duration of vertical arrangement operations was significantly lower than that of horizontal arrangement operations; (2) the evaluation values of vertical arrangements were significantly higher than those of horizontal arrangements; (3) both average amplitudes of fixational eye movements in vertical arrangement operations and evaluations were significantly higher than those in horizontal arrangement operations and evaluations respectively. The results indicated that vertical arrangements tended to be more visually aesthetic than horizontal arrangements for Chinese characters.

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63.4098 **Effect of Stroke Frequency and Critical Contrast Component on Legibility of Outlined and Solid Chinese Characters** Aoi Takahashi[1](aoco.t.r2@gmail.com), Koichi Oda[1]; [1]The Graduate School of Tokyo Woman's Christian University

Objective: Some studies show legibility of characters are strongly affected by their stroke frequencies (Majaj, et. al, 2002; Zhung et. al, 2007). Takahashi and Oda (2014) showed the legibility was well explained by stroke frequency and observers' visual acuity for Chinese characters in a very wide range of stroke frequency using outlined(OFS) and solid font style(SFS). Their results also showed a systematic difference in legibility between OFS and SFS which could not be explained by stroke frequency and observers' acuity. The objective is to see whether the critical contrast component for character recognition (1-4 cycles per character(cpc) component) explains the difference. Method: Stimuli and apparatus were the same as Takahashi and Oda(2014). Stimuli were Chinese characters of 3 complexity levels, high: 16, middle: 8, and low: 2-3 stroke frequencies per character with 10 characters in each group. These 30 characters were presented in two font styles, i.e., OFS and SFS of Kozuka Gothic ProN. The line width of OFS was 1/24 of character height. Twelve university students with normal acuity participated in the threshold measurement and legibility was defined as character size for 50% recognition threshold for each character. The critical contrast component of 1-4 cpc was calculated with FFT for each character. We compared the coefficient of determination between two multiple regression analyses, i.e., one by stroke frequency and the other with stroke frequency and the critical contrast component. Result and Discussion: The R^2 for the model with two factors was 0.993 and better than one for the model with stroke frequency only. However, the resulted regression model predicts that characters with higher contrast components are less legible. We suspect that the effect of the critical contrast component would depend on stroke frequency.

63.4099 **Can you recognize two words at once? Characterizing capacity limits in the visual processing of words** Alex White[1](alexlw@uw.edu), John Palmer[1], Geoffrey Boynton[1]; [1]Department of Psychology, University of Washington

Background: Reading is constrained by inherent limitations of the visual system. For instance, you cannot comprehend this whole paragraph at once. Beyond the limitations of peripheral vision that require saccades to scan the page, additional capacity limits could impair simultaneous processing of even just two words visible during a single fixation. Such capacity limits would impair performance when observers attempt to recognize two words at once compared to just one, as previous research in our lab has found. Here, we applied dual- and single-task paradigms to investigate the capacity limits for semantic recognition of multiple words compared to judging their lower-level features. Methods: Words appeared in rapid serial visual presentation simultaneously to the left and right of fixation. In dual-task conditions, observers made independent judgments regarding the presence of target words in both locations. In single-task conditions, observers focused their attention to judge words on only one side. Simple feature tasks required the detection of increments in luminance or color saturation of the words. Semantic categorization required deeper processing of the same stimuli, for instance detecting an animal word among other nouns. For each type of task, we quantified the dual-task deficit and compared it to the predictions of three signal detection models: an unlimited-capacity parallel model, a fixed-capacity parallel model, and the standard serial model (one word at a time). Results: Simple feature tasks showed no dual-task deficits (no divided attention effects), consistent with previous results. Semantic categorization of the same stimuli suffered reliable deficits that were consistent with the fixed-capacity parallel model. We conclude that words need not be processed in serial, and indeed simple features of two words can be processed in parallel with no cost. Higher-level linguistic processing, however, is capacity-limited such that recognition is best when processing just one word at a time.

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63.4100 **The field of view of word-responsive regions in visual cortex** Rosemary Le[1,2](rosemary.le@stanford.edu), Brian Wandell[1,2], Michal Ben-Shachar[3,4], Nathan Witthoft[1,2]; [1]Psychology Department, Stanford University, [2]Center for Cognitive and Neurobiological Imaging, Stanford University, [3]Gonda Multidisciplinary Brain Research Center, Bar Ilan University, [4]Department of English Literature and Linguistics, Bar Ilan University

Introduction Skilled reading involves rapid recognition of foveally-presented word forms. fMRI measurements have shown that regions in ventral occipito-temporal cortex are trained to rapidly recognize word forms, but the spatial sensitivity of these regions is not well understood. Here we measure its field of view – the portion of the visual world that reliably evokes a response in these regions. We examine how the field of view is modulated by stimulus type. Methods We used population receptive field (pRF) methods to measure the field of view in word-responsive cortex. Two types of stimuli – words and checkerboards – were used as the contrast pattern in bars that swept through the visual field (16° radius). The responses were modeled using the compressive summation model (Kay 2013). Separate pRF models were fit to each stimulus type. The visual word form area (VWFA) and its right-hemisphere homolog (rVWFA) were functionally localized in each subject (n = 21). Results When measured with word stimuli, the field of view of the VWFA is elliptical and extends from the fovea to 5-7° along the horizontal meridian. More than 90% of the pRF centers within the VWFA are within 5° eccentricity. The same trend can be seen in rVWFA. The field of view of word-responsive regions shows a bias for the right lower visual field. When the pRFs are measured with checkerboard stimuli, the same regions show noisier and less consistent field of view across subjects. In contrast, the field of view in V1 is highly consistent for all stimuli. Discussion In response to word stimuli, the field of view of word-responsive regions is foveally-biased. The field of view of word-responsive cortex, but not V1, is stimulus dependent. These findings provide a new paradigm for studying cortical responses in relation to individual reading performance.

Visual memory: Long-term memory, models, and integrative processes

Wednesday, May 18, 8:30 am - 12:30 pm

Poster Session, Pavilion

63.4101 Accessing without remembering: memory consolidation of information at the focus of awareness is optional

Hui Chen[1](psychenhui@gmail.com), Brad Wyble[1]; [1]The Pennsylvania State University

It is well known that fleeting or phenomenal awareness will not necessarily lead to memory consolidation, as shown by iconic memory or post-masking studies, but it is generally assumed that information that reaches a state of full awareness will be consolidated into memory. A recent study challenged this assumption by showing that participants can exhibit a striking inability to report information that they had just accessed from a visual display when given a surprise question (i.e. Attribute Amnesia; Chen & Wyble, 2015). However, this paradigm could not conclusively determine whether the effect is due to forgetting caused by the surprise question or a failure to consolidate the information. A new series of experiments reveals that it is possible to have awareness of a specific stimulus attribute and yet fail to consolidate that information into memory. Specifically, participants were presented a colored fixation cross simultaneously with four different colored letters and asked to locate the target letter with the same color as the fixation cross for numerous repetitions. Then on a surprise trial they were asked to report the color of the target letter before reporting its location. In this case participants could not report the color even though they had just used that color to locate the target. However, in a parallel experiment performance on the surprise question was much better once participants were forced to store and hold the unmasked fixation color for just 100ms before using it to locate the target letter. These findings suggest that awareness is not sufficient to create a robust memory representation and that there is a subsequent memory consolidation process which is selectively employed only if the task requires it. Further implications of these results regarding the relationship among attention, awareness, and memory will be discussed.

63.4102 Contextual Adaptation to Changes of „What“ and „Where“ – Learning of Object Identity and Spatial Configuration in Visual Search

Markus Conci[1](conci@psy.lmu.de), Martina Zellin[1], Hermann Müller[1]; [1]Department of Psychology, Ludwig-Maximilians-University, Munich, Germany

In order to deal with our complex visual environment, human observers have developed the capability to extract a variety of statistical regularities from our ambient array, thereby facilitating attentional orienting. For instance, in visual search, detection of a target is faster when the spatial configuration or the object identities of nontarget items are repeatedly encountered. These results show that both spatial and object-based contextual invariances can implicitly guide attention to the target (contextual cueing; Chun, 2000, Trends Cogn. Sci., for review). Here, we explored how such acquired contextual regularities can be adapted subsequent to an unexpected environmental change (see Zellin et al., 2014, Psychonomic Bull. Rev.). A series of experiments were performed in which, in an initial learning phase, observers learned to associate a given repeated context of nontargets with a given target. A subsequent test phase then introduced identity and/or location changes to the target. Our results show that observers were rather ineffective in adapting to a change of the spatial location, or to the object identity of the target. However, when the change to the target occured both in terms of its identity and in location, then contextual cueing was effective again shortly after the change – showing that successful adaptation occurred. These results suggest that contextual learning is capable to efficiently extract regularities relating to the spatial configuration and to object identity at first. However, contextual learning, once acquired, is rather insensitive to adapt, at least, as long as it does not reveal a „rich“, i.e., redundant change signal that combines both spatial- and object-based scene statistics.

Acknowledgement: German Research Foundation (DFG, grant: FOR 2293/1)

63.4103 Overlap and separation of remembered and perceived visual information in the human medial temporal lobe

J. Benjamin Hutchinson[1](jhutchin@princeton.edu), Yida Wang[2], Nicholas Turk-Browne[1]; [1]Department of Psychology, Princeton University, [2]Department of Computer Science, Princeton University

When we recall a past experience, rich sensory details often come to mind. Indeed, remembering engages the same perceptual regions of our brain as were active when we initially had the experience. Although this representational overlap between memory and perception may be advantageous to the phenomenology of recollection, it raises the question of how the brain distinguishes internally from externally generated information. Here, we hypothesized that, within the temporal lobe, overlap across memory and perception would be restricted to regions coding predominantly for visual features, such as in parahippocampal cortex, and not found in regions like the hippocampus that are strongly influenced by spatiotemporal information that discriminates past and present. Prior to an fMRI session, 24 observers were asked to form mental associations between pairs of images (each pair consisted of a unique face and scene). While being scanned, they were presented with blocks of images from one category, one image appearing at a time, and performed a simple categorization judgment (male vs. female for faces; natural vs. urban for scenes). Critically, they were cued to base their judgments either on the images being viewed (‘perceive’ condition) or, from memory, on the images that had been paired with those images beforehand (‘retrieve’ condition). Consistent with our hypothesis, scene-selective parahippocampal cortex showed greater pattern similarity across voxels when perceiving and retrieving the same vs. different scenes. As hypothesized, this was not observed in the hippocampus, but more unexpectedly, the effect was significantly reversed: there was greater pattern dissimilarity (anti-correlation) across voxels when perceiving and retrieving the same vs. different scenes. This finding suggests that the hippocampus can separate or differentiate representations of the same visual features when they are encountered at different points in time and/or arise from different sources (internal or external).

Acknowledgement: NIH R01 EY021755

63.4104 Intersubject similarity of mulitvoxel codes in perirhinal cortex reflects the typicality of visual objects

Amy Price[1](amyroseprice@gmail.com), Michael Bonner[1], Jonathan Peelle[2], Murray Grossman[1]; [1]Center for Cognitive Neuroscience, University of Pennsylvania, [2]Department of Otolaryngology, Washington University in St. Louis

The ventral visual pathway transforms perceptual inputs of objects into increasingly complex representations, and its highest stages are thought to contain abstract semantic codes. A key function of these semantic codes is to provide a common understanding of visual objects across individuals. For example, my stored knowledge of the familiar object “red apple” should be similar to yours if we are to communicate and coordinate our behaviors. This predicts a specific functional architecture: neural codes of visual-semantic regions are structured to provide a common ground between observers of the visual world. Here we tested for a key signature of this proposed architecture by: 1) identifying regions encoding high-level object meaning and 2) testing whether inter-subject similarity in these regions tracks object meaning. During fMRI, subjects viewed objects created from combinations of shapes (apples, leaves, roses) and colors (red, green, pink, yellow, blue) while performing an unrelated target-detection task. For each object set, we created a semantic-similarity model based on the co-occurrence frequencies of color-object combinations (e.g., “yellow apple”) from a large lexical corpus (Fig-1A). These models were orthogonal to perceptual models for shape or color alone. Using representational similarity analysis, we found that perirhinal cortex was the only region that significantly correlated with the semantic-similarity model ($p< 0.01$; Fig-1B). Next, we hyper-aligned each subject’s data to a common, high-dimensional space in a series of anatomic regions. We predicted that in visual-semantic regions, inter-subject similarity would be related to the semantic typicality of the objects. Indeed, we found that perirhinal cortex was unique in containing population codes for which inter-subject similarity increased with object typicality (Fig-1C&D). Our results suggest that high-level regions at the interface of vision and memory encode combinatorial information that underlies real-world knowledge of visual objects and may instantiate a neural “common ground” for object meaning across individuals.

63.4105 Neural architecture for binding in visual working memory

Paul Bays[1](pmb20@cam.ac.uk); [1]Department of Psychology, University of Cambridge

Binding refers to the information that groups different features together into objects. In probed recall tasks, binding failure is associated with swap errors, in which observers report an item other than the one indicated by the probe. To investigate the basis of swap errors, we presented observers with a memory display consisting of six coloured discs. After a delay they were asked to report, on a continuous scale, either the colour they had seen at a specified location, or the location that corresponded to a specified colour. Swap errors were observed to occur most frequently for items that were similar to the target in the probe feature-dimension, while swap frequency fell to chance for the most dissimilar items, indicating that variability in memory for the probe feature was responsible for swaps. These observations were reproduced by a model of population coding, in which visual information was encoded in the noisy activity of a single population of neurons with conjunction (colour × location) responses. Maximum likelihood decoding of population activity resulted in errors that quantitatively reproduced the behavioural distributions of recall error, the frequency of swaps, and the relationship between swap frequency and probe-dimension similarity. These results demonstrate a neural architecture that could underlie binding in working memory.

Acknowledgement: Wellcome Trust

63.4106 The role of memory uncertainty in change detection

Aspen Yoo[1,2](aspen.yoo@nyu.edu), Luigi Acerbi[1,2], Emin Orhan[1,2], Wei Ji Ma[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Although change detection is a leading visual short-term memory (VSTM) paradigm, it is still unclear exactly what information is stored and used during a change detection trial. The traditional view was that an item is stored in an all-or-none fashion. Recent work has shown that VSTM is better described as storing a noisy measurement of a stimulus. Here, we take this notion a step further and hypothesize that the level of uncertainty associated with a noisy stimulus memory is also stored and is taken into account during the decision. Subjects remembered the orientation of an ellipse and responded whether that orientation was different from a line segment's orientation presented after a delay. We manipulated VSTM uncertainty through ellipse elongation. The data were best fitted by a model in which the observer takes uncertainty into account, although not optimally. This result suggests that visual short-term memories are probabilistic and that change detection is a form of probabilistic inference. We then asked how a neural circuit could implement probabilistic change detection. We trained a recurrent two-layer neural network consisting of generic nonlinear units using trial-to-trial feedback. Training stimuli were encoded by a population of orientation-selective Poisson neurons. We found that given enough training trials, the network performs the task near-optimally, develops an explicit representation of the probability that a change occurred, and generalizes to new and variable stimulus reliabilities. Examining the dynamics of the network, we found that few hidden units exhibit the persistent activity long believed to be essential for the maintenance of a memory. Instead, most units are active only during a portion of the delay period, consistent with recent physiology. Together, our results suggest a new conceptualization of change detection at both the behavioral and the neural level.

63.4107 Testing Predictions of the Binding Pool model

Garrett Swan[1](gsp.swan@gmail.com), Brad Wyble[1]; [1]Psychology, Liberal Arts, Penn State University

An important role of computational models is the development of testable predictions. Here, we summarize results from testing 6 predictions concerning the Binding Pool, a computational model of visual working memory, in Swan and Wyble (2014). Prediction 1: Forgetting an object from memory should improve the precision of other stored objects. This was tested by measuring memory precision when participants were cued to forget one item during a retention interval (see also Williams et al., 2013). Prediction 2: Memory precision should decline as more features are encoded. We tested this prediction by changing the number of features reported from a single object. Participants were less precise when reporting more features. Prediction 3: Reports of features from repetitions of objects should be less precise than from a single object. Contrary to the prediction, when testing recall we found similar precision values for three repetitions as a single color. Prediction 4 pertained to confidence for repeated items and was similarly not matched by the data. Prediction 5: Two similar features should bias precision of a third feature more than dissimilar features. In an experiment, participants reported the luminance of one square while we manipulated the luminance of two other squares in the memory set. The data did not support the prediction since bias was stronger for the dissimilar features. Prediction 6: Swap errors should produce high confidence responses. We validated this prediction by looking at high confident responses with high error and found that the corresponding responses were best fit by the non-target distribution instead of a uniform distribution. The failed predictions pertain to retrieval of repeated values and thus highlight the model's inability to use ensembles to compress repeated information. Future work will explore how ensemble representations should be incorporated to allow the model to represent repeated items more efficiently.

63.4108 The Functional Role of Imagery in Generative Models of Visual Perceptions

Ghislain St-Yves[1](ghis.styves@gmail.com), Thomas Naselaris[1]; [1]Department of Neurosciences, Medical University of South Carolina

There is growing empirical evidence that visual perception and mental imagery, i.e. the conjuring of a visual percept in absence of external visual stimuli, operate on the same neural substrate [Albright, 2012]. This strongly suggests that imagery is an integral part of seeing, in favor of generative models of visual processing where the generative machinery can be harnessed even in absence of stimuli. In addition, generative models can be adapted to explain many otherwise puzzling observations of neural activity patterns like extra-classical receptive-field responses [Rao and Ballard, 1999] and the emergence of vivid hallucinations in certain conditions of degraded visual input [Reichert et al., 2013]. Here, we are interested in the consequences of generative models for the process of mental imagery. In the models, the neural activity generated during mental imagery results entirely from predictive signaling. We will show how interpreting mental imagery in this way offers an explanation of why mental imagery decoding can work at all [Naselaris et al., 2015], why it is not easy, and explore the factors that limit the precision of mental images. In our framework, mental imagery decoding is possible because the independent activa- tion of high-level visual areas during imagery induces activity in early visual areas that is strongly correlated with the activity during perception. We also show that, in accord with the common observations during measurements of BOLD activity in fMRI studies during mental imagery tasks, the modeled activity in regions that encode generic image features (low-level) is generally much weaker than during the corresponding perception task. This contributes to the difficulty of decoding mental images. More importantly however, we show that the character of the high-level features encoded in a deep generative model places an inherent limitation on how faithfully a mental image can emulate a corresponding visual percept.

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63.4109 A new vocabulary for understanding limits on perception

Chris Sims[1](chris.sims@drexel.edu), Rachel Lerch[1]; [1]Department of Psychology, Drexel University

Human perceptual processing, like any physical information channel, is by necessity capacity-limited. However, limits on channel capacity are only one factor that is relevant for understanding what makes for an 'optimal' or 'efficient' communication system. Perceptual systems exist not merely to transmit information, but rather to allow organisms to accomplish behavioral goals. Hence, an optimal perceptual system is one that minimizes the task-relevant costs of perceptual error (defined by a particular cost function) subject to a limit on capacity. The mathematical field of rate–distortion theory provides the theoretical tools necessary for studying this problem. Importantly, in this framework the optimality of a given perceptual system depends critically on three factors: (1) limits on capacity, (2) limits on statistical learning, and (3) the match between the implicit and explicit cost function for a given task. Research on visual perception and visual memory has focused almost exclusively on understanding capacity or resource limits, while the latter two constructs have been largely overlooked. Hence, rate–distortion theory provides a much richer vocabulary for understanding perceptual processing, and yields novel and unique predictions for human performance. We applied this framework to two benchmark domains in the study of perception: the discrete categorization of perceptual signals (also known as absolute identification) and perceptual working memory. In each case rate–distortion theory provides a quantitative fit to the data that is better than or comparable to the best published models in the literature. We argue that human perceptual performance is explained by three equally important factors, not just limits on capacity. Perceptual processing must also be understood in terms of the implicit cost function it seeks to minimize, as well as limits in implicit statistical learning.

63.4110 The Role of Amodal Object-based Attention in Retaining Bindings in Working Memory

Fan Wu[1](ivanwoo1989@yahoo.com), Hong Ma[1], Kaifeng He[1], Yue Yang[1], Zaifeng Gao[1], Mowei Shen[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

Over the past decade, it has been debated whether retaining bindings in working memory requires more attention than retaining constituent features, focusing on domain-general attention and space-based attention. In the current study we hypothesized that retaining bindings in working memory needs more amodal object-based attention than retaining single features. In a change detection task, we tested three typical bindings, which had been suggested requiring no more attention than the constituent features: The two constituent features of binding were stored in different working memory modules (cross-module binding, Experiment 1), from auditory and visual modalities (cross-modal binding, Experiment 2), or spatially separated (cross-space visual binding, Experiments 3 and 4). In the critical condition, we added a secondary object feature-report task during the delay interval of the change-detection task, such that the secondary task competed for object-based attention with the to-be-memorized stimuli. Moreover, the secondary task was presented in either visual (Experiments 1-3) or auditory (Experiment 4) modality. If more amodal object-based attention is required for retaining bindings than for retaining constituent features in working memory, the attention-demanding secondary task should impair the binding performance to a larger degree relative to the performance of constituent features. In congruent with this prediction, Experiments 1–4 consistently revealed a significantly larger impairment for bindings than for the constituent features, regardless of the modality of the secondary task.

Acknowledgement: National Natural Science Foundation of China (31271089, 31571119, and 61431015)

63.4111 **Visual working memory is spatially global: boundaries in the similarity of visually perceived and internally represented stimuli** Geoffrey Harrison[1](8gh3@queensu.ca), Daryl Wilson[1]; [1]Queen's University

An emerging framework suggests that visual working memory (WM) representations rely on the same representational resources as those used to process external visual input. Kiyonaga and Egner (2014) provided support for this claim by demonstrating with a modified WM Stroop task that an irrelevant color word held in WM produces the same Stroop interference patterns on a perceptual color target as that seen in a classic perceptual Stroop task. However, there is evidence that perceptual and WM representations differ in terms of their spatial representation. Specifically, unlike visually perceived stimuli, the representation of information in WM might be spatially global rather than tied to any specific retinotopic location (Ester, Serences, & Awh, 2009). To test the spatial specificity of WM representations, we compared a classic perceptual Stroop task with a WM version in which the color word and color patch appeared either in the same or a different spatial location. In Experiment 1, for the perceptual version, we found a spatial effect such that spatial separation eliminated Stroop interference. However, in the WM Stroop task, robust Stroop interference was demonstrated in both the spatially overlapping and spatially separated conditions. In Experiment 2, we ensured location of the color word was encoded into WM by only testing memory for the color word's location. At test, the color word either appeared in the same spatial location or at a spatially displaced location—the extent of which was modified throughout the task to ensure motivated encoding. Replicating the results of Experiment 1, spatial separation eliminated Stroop interference for the perceptual task, but was present for both spatially overlapping and spatially separated conditions of the WM Stroop task. These experiments support the conclusion that at least in terms of spatial information, perceptual and WM representations do not rely on the same neural machinery.

Acknowledgement: NSERC

63.4112 **Individual differences in depth discrimination predicts differences in visual working memory for stimuli rendered in 3D** Chaipat Chunharas[1](cchunharas@gmail.com), Sirawaj Itthipuripat[1,2], Thomas Sprague[1,2], Edward Ester[1], John Serences[1,2]; [1]Department of Psychology, University of California, San Diego, [2]Neurosciences Graduate Program, University of California, San Diego

Most visual working memory (vWM) studies have used 2-dimensional displays even though we routinely encode information in 3D. The addition of depth information might enhance vWM performance by reducing competition between nearby stimuli, or it might impair vWM performance because it extends the spatial extent of attention across the visual field. To evaluate these possibilities, we ran two tasks that induced depth perception using binocular disparity. First, subjects performed a depth-discrimination task in which they had to report whether the target was presented in front of or behind fixation. Then, they performed a delayed-match-to-sample vWM paradigm with set-sizes of 2, 4, 6, 8 and 12. The stimuli were either all presented in the same plane (2D condition) or equally distributed across two depth planes (3D condition). We found a strong correlation between depth discrimination ability in the first task and differences in vWM performance between 3D vs. 2D conditions in the second task – subjects who were better at perceiving depth had selectively higher memory capacity in the 3D vs the 2D vWM task (rho 0.584, p-value 0.0043). This correlation grew increasingly strong with increasing set-size in the vWM task, suggesting that the ability to exploit depth information gave more benefits as the memory load increased.

63.4113 **Identity and Spatial Cues Can Improve Filtering Ability in Visual Working Memory** Ayala Allon[1](ayalaallon@gmail.com), Roy Luria[1,2]; [1]School of Psychological Sciences, Tel-Aviv University, [2]Sagol School of Neuroscience, Tel-Aviv University

Previous research suggested that filtering efficiency (the ability to ignore task irrelevant items) might explain individual differences in Visual Working Memory (VWM) capacity, such that high-capacity individuals have better control over VWM limited workspace by encoding and maintaining only task relevant information. Here, we investigated possible compensation mechanisms for improving filtering performance in VWM. Specifically, we investigated whether an identity cue that singled the upcoming appearance of distractors among targets, a spatial cue marking the locations of distractors (placeholders), or a combination of both cues can improve filtering performance in VWM. Participants performed a change-detection task in which they had to memorize the color of the targets with either three targets, six targets, or three targets and three distractors (the filtering condition). In Experiment 1 we used an identity cue, in Experiment 2 we used placeholders to mark the locations of the distractors and held these locations fixed throughout the experiment, and in Experiment 3 we used both cues. We found that each cue alone was not sufficient to improve filtering performance, but using both cues did improve filtering performance. In Experiment 4, manipulating the preparation interval prior to a filtering trial did not further improve filtering performance. In addition, in Experiment 5 a spatial cue alone was able to ameliorate filtering performance as long as the locations of the distractors were randomly changed throughout the experiment. Furthermore, in Experiment 6, removing the placeholders but keeping the distractors locations fixed was not sufficient for the identity cue to improve filtering performance. These findings suggest that when the spatial variability of the distractors is low, only interactions between high processes such as executive functions and low processes such as spatial separation between the distractors and the targets, can improve filtering ability in VWM.

63.4114 **A task-irrelevant high memorability image can impair or enhance visual search performanc** Qi Li[1](riki0803@gmail.com), Kazuhiko Yokosawa[1]; [1]The University of Tokyo

Some images are remembered at first glance, while others are forgotten quickly. A recent study has demonstrated that images carry the property of memorability (Isola, Xiao, Parikh, Torralba, & Oliva, 2014). An important question that arises from their study is what factors interact with memorability. Isola et al. (2014) have investigated factors that are intrinsic to an image such as aesthetics, simple features and semantic attributes. Our study focused on a possible factor that is extrinsic to an image — visual attention. Specifically, we used the concurrent visual search task (Wolfe, Horowitz & Michod, 2007) to investigate the interplay between image memorability and visual attention. Experiment 1 tested whether high and low memorability images capture visual attention in a different way. Participants viewed an L versus T search array that was superimposed over a task-irrelevant image on each trial. The task was to count the number of Ts presented on each trial (There could be 0, 1 or 2 Ts). Search performance was significantly impaired by high memorability images compared to low memorability images, suggesting that task-irrelevant high memorability images are difficult to ignore and capture visual attention automatically. Experiment 2 further examined whether presenting a task-irrelevant image prior to the search display can produce similar effects as those observed in Experiment 1. Interestingly, the results revealed that search performance was significantly enhanced by high memorability images that preceded the search display. A plausible explanation is that the participants were more alert and active after viewing a high memorability image, leading to improvements in search performance.

63.4115 **Saccades inevitably protect visual memory traces** Sven Ohl[1,2](sven.ohl@bccn-berlin.de), Martin Rolfs[1,2]; [1]Department of Psychology, Humboldt Universität zu Berlin, [2]Bernstein Center for Computational Neuroscience Berlin

With each visual fixation, a vast amount of information enters the visual system, only part of which will be stored durably in visual short-term memory (VSTM). We present four experiments testing the hypothesis that saccadic eye movements decide upon the content of VSTM, and determine naturally what we remember and what we forget. We studied whether saccades, planned and executed after the disappearance of a visual stimulus array, influence memory performance even if the saccade is irrelevant to the memory task. We flashed briefly (100 ms) an array of oriented Gabor patches and—after a variable delay—prompted saccades to a random (now empty) location in the array. Subsequently, a response cue instructed observers to report the orientation of one randomly selected stimulus in the array, probing memory either at the same (congruent) or at a different location than the saccade target (incongruent). In all experiments, memory performance was markedly better when the probed location and the saccade target coincided. This effect of saccades on visual memory was time-dependent; it was strongest right after array offset, still present after 800 ms, and no longer significant after 1600 ms (Experiment 1). In contrast, the performance difference between congruent and incongruent trials remained constant across a large range of intervals between saccade cue and the onset of the response cue (Experiment 2). Masking the memory array up to 800 ms after its offset—but simultaneously with the onset of the saccade cue—reduced performance, yet a congruency effect remained (Experiment 3). Finally, we show that this impact of saccades on VSTM is inevitable even when congruent trials are far less likely than incongruent ones (Experiment 4). These results demonstrate that saccades inadvertently determine the content of VSTM, imposing a natural bottleneck on the transition of fragile sensory traces to durable memories.

Acknowledgement: DFG Emmy Noether grant (RO 3579/2-1) DFG Research grant (OH274/2-1 and RO3579/6-1)

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Topic Index

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May 13-18, 2016

St. Pete Beach, Florida