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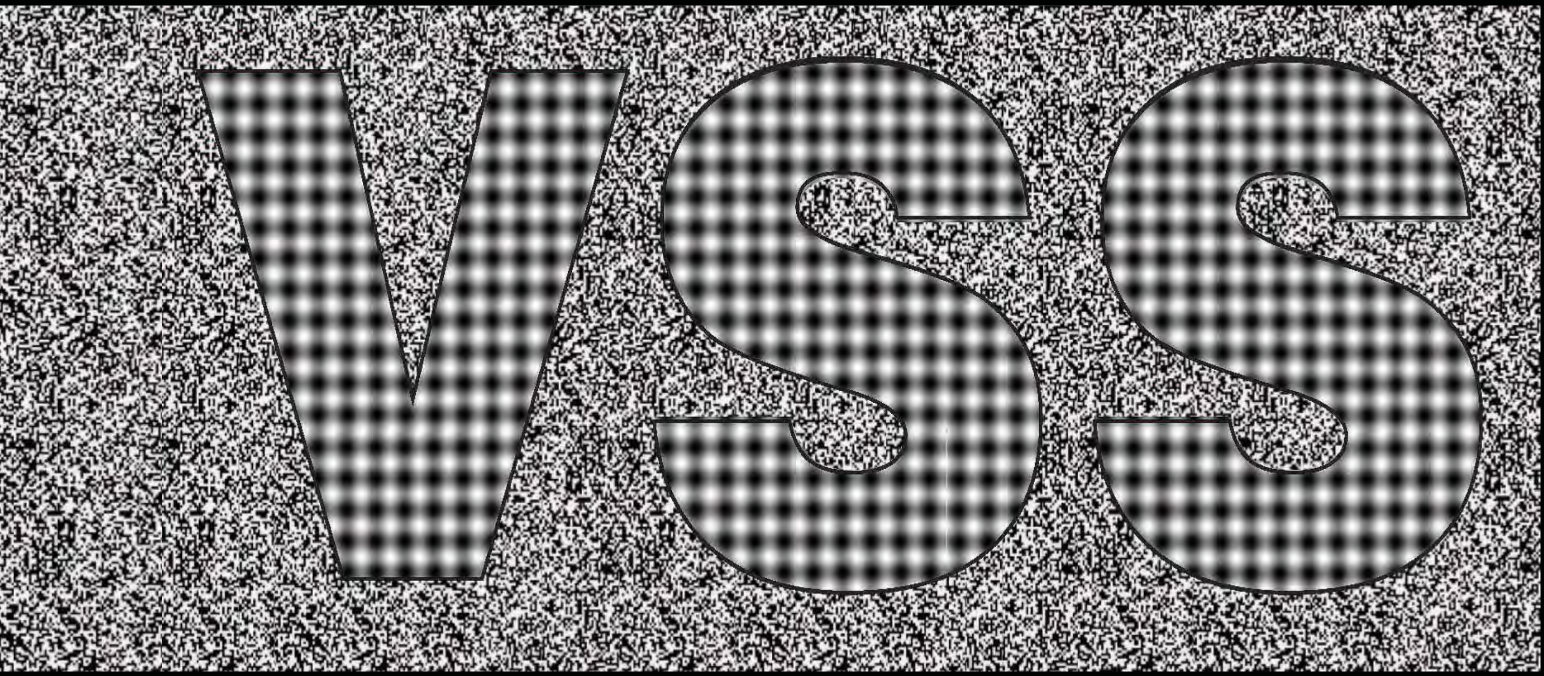

Vision Sciences Society

Abstracts

Vision Sciences Society

18th Annual Meeting, May 18-23, 2018
TradeWinds Island Resorts, St. Pete Beach, Florida

Abstracts

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Sessions Overview

Abstract Numbering System

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

First Digit - Day	Second Digit - Time	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	01, 02... For posters
4 Monday	3 AM poster session	3 Banyan Breezeway	
5 Tuesday	4 Early PM talk session	4 Pavilion	
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Examples

21.16 Saturday, early AM talk in Talk Room 1, 6th talk
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Note: Two digits after the period indicates a talk, three digits indicates a poster (the last two digits are the board number).

Member-Initiated Symposia

Schedule Overview

Friday, May 18, 2018, 12:00 - 2:00 pm

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S5 **Visual remapping: From behavior to neurons through computation** Talk Room 1

S6 **Advances in temporal models of human visual cortex** Talk Room 2

S1 Clinical insights into basic visual processes

Friday, May 18, 2018, 12:00 - 2:00 pm, Talk Room 1

Organizers: Paul Gamlin, University of Alabama at Birmingham; Ann E. Elsner, Indiana University; Ronald Gregg, University of Louisville

Presenters: Geunyoung Yoon, Artur Cideciyan, Ione Fine, MiYoung Kwon

This year's biennial ARVO at VSS symposium features insights into human visual processing at the retinal and cortical level arising from clinical and translational research. The speakers will present recent work based on a wide range of state-of-the art techniques including adaptive optics, brain and retinal imaging, psychophysics and gene therapy.

12:02 pm Neural mechanisms of long-term adaptation to the eye's habitual aberration

Speaker: Geunyoung Yoon, Flaum Eye Institute, Center for Visual Science, The Institute of Optics, University of Rochester

Understanding the limits of human vision requires fundamental insights into both optical and neural factors in vision. Although the eye's optics are far from perfect, contributions of the optical factors to neural processing are largely underappreciated. Specifically, how neural processing of images formed on the retina is altered by the long-term visual experience with habitual optical blur has remained unexplored. With technological advances in an adaptive optics vision simulator, it is now possible to manipulate ocular optics precisely. I will highlight our recent investigations on underlying mechanisms of long-term neural adaptation to the optics of the eye and its impact on spatial vision in the normally developed adult visual system.

12:27 pm Human Melanopic Circuit in Isolation from Photoreceptor Input: Light Sensitivity and Temporal Profile

Speaker: Artur Cideciyan, Scheie Eye Institute, Perelman School of Medicine, University of Pennsylvaniat

Leber congenital amaurosis refers to a group of severe early-onset inherited retinopathies. There are more than 20 causative genes with varied pathophysiological mechanisms resulting in vision loss at the level of the photoreceptors. Some eyes retain near normal photoreceptor and inner retinal structure despite the severe retina-wide loss of photoreceptor function. High luminance stimuli allow recording of pupillary responses driven directly by melanopsin-expressing intrinsically photosensitive retinal ganglion cells. Analyses of these pupillary responses help clarify the fidelity of transmission of light signals from the retina to the brain for patients with no light perception undergoing early phase clinical treatment trials. In addition, these responses serve to define the sensitivity and temporal profile of the human melanopic circuit in isolation from photoreceptor input.

12:52 pm Vision in the blind

Speaker: Ione Fine, Department of Psychology, University of Washington

Individuals who are blind early in life show cross-modal plasticity – responses to auditory and tactile stimuli within regions of occipital cortex that are purely visual in the normally sighted. If vision is restored later in life, as occurs in a small number of sight recovery individuals, this cross-modal plasticity persists, even while some visual responsiveness is regained. Here I describe the relationship between cross-modal responses and persisting residual vision. Our results suggest the intriguing possibility that the dramatic changes in function that are observed as a result of early blindness are implemented in the absence of major changes in neuroanatomy at either the micro or macro scale: analogous to reformatting a Windows computer to Linux.

1:17 pm Impact of retinal ganglion cell loss on human pattern recognition

Speaker: MiYoung Kwon, Department of Ophthalmology, University of Alabama at Birmingham

The processing of human pattern detection and recognition requires integrating visual information across space. In the human visual system, the retinal ganglion cells (RGCs) are the output neurons of the retina, and human pattern recognition is built from the neural representation of the RGCs. Here I will present our recent work demonstrating how a loss of RGCs due to either normal aging or pathological conditions such as glaucoma undermines pattern recognition and alters spatial integration properties. I will further highlight the role of the RGCs in determining the spatial extent over which visual inputs are combined. Our findings suggest that understanding the structural and functional integrity of RGCs would help not only better characterize visual deficits associated eye disorders, but also understand the front-end sensory requirements for human pattern recognition.

S2 Vision and visualization: Inspiring novel research directions in vision science

Friday, May 18, 2018, 12:00 - 2:00 pm, Talk Room 2

Organizers: Christie Nothelfer, Northwestern University; Madison Elliott, UBC, Zoya Bylinskii, MIT; Cindy Xiong, Northwestern University; Danielle Albers Szafir, University of Colorado Boulder

Presenters: Ronald A. Rensink, Aude Oliva, Steven Franconeri, Danielle Albers Szafir

Data is ubiquitous in the modern world, and its communication, analysis, and interpretation are critical scientific issues. Visualizations leverage the capabilities of the visual system, allowing us to intuitively explore and generate novel understandings of data in ways that fully-automated approaches cannot. Visualization research builds an empirical framework around design guidelines, perceptual evaluation of design techniques, and a basic understanding of the visual processes associated with viewing

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data displays. Vision science offers the methodologies and phenomena that can provide foundational insight into these questions. Challenges in visualization map directly to many vision science topics, such as finding data of interest (visual search), estimating data means and variance (ensemble coding), and determining optimal display properties (crowding, salience, color perception). Given the growing interest in psychological work that advances basic knowledge and allows for immediate translation, visualization provides an exciting new context for vision scientists to confirm existing hypotheses and explore new questions. This symposium will illustrate how interdisciplinary work across vision science and visualization simultaneously improves visualization techniques while advancing our understanding of the visual system, and inspire new research opportunities at the intersection of these two fields.

Historically, the crossover between visualization and vision science relied heavily on canonical findings, but this has changed significantly in recent years. Visualization work has recently incorporated and iterated on newer vision research, and the results has been met with great excitement from both sides (e.g., Rensink & Baldridge, 2010; Haroz & Whitney, 2012; Harrison et al., 2014; Borkin et al., 2016; Szafir et al., 2016). Unfortunately, very little of this work is presented regularly at VSS, and there is currently no dedicated venue for collaborative exchanges between the two research communities. This symposium showcases the current state of vision science and visualization research integration, and aspires to make VSS a home for future exchanges. Visualization would benefit from sampling a wider set of vision topics and methods, while vision scientists would gain a new real-world context that simultaneously provokes insight about the visual system and holds translational impact.

This symposium will first introduce the benefits of collaboration between vision science and visualization communities, including the discussion of a specific example: correlation perception (Ronald Rensink). Next, we will discuss the properties of salience in visualizations (Aude Oliva), how we extract patterns, shapes, and relations from data points (Steven Franconeri), and how color perception is affected by the constraints of visualization design (Danielle Albers Szafir). Each talk will be 25 minutes long. The speakers, representing both fields, will demonstrate how studying these topics in visualizations has uniquely advanced our understanding of the visual system, as well as what research in these cross-disciplinary projects looks like, and propose open questions to propel new research in both communities. The symposium will conclude with an open discussion about how vision science and visualization communities can mutually benefit from deeper integration. We expect these topics to be of interest to VSS members from a multitude of vision science topics, specifically: pattern recognition, salience, shape perception, color perception, and ensemble coding.

12:01 pm Information Visualization and the Study of Visual Perception

Speaker: Ronald A. Rensink, Departments of Psychology and Computer Science, UBC

Information visualization and vision science can interact in three different (but compatible) ways. The first uses knowledge of human vision to design more effective visualizations. The second adapts measurement techniques originally developed for experiments to assess performance on given visualizations. And a third way has also been recently proposed: the study of restricted versions of existing visualizations. These can be considered as “fruit flies”, i.e., systems that exist in the real world, but are still simple enough to study. This approach can help us discover why a visualization works, and can give us new insights into visual perception as well. An example of this is the perception of Pearson correlation in scatterplots. Performance here can be described by two linked laws: a linear one for discrimination and a logarithmic one for perceived magnitude (Rensink & Baldridge, 2010). These laws hold under a variety of conditions, including when properties other than spatial position are used to convey information (Rensink, 2014). Such behavior suggests that observers can infer probability distributions in an abstract two-dimensional parameter space (likely via ensemble coding), and can use these to estimate entropy (Rensink, 2017). These results show that interesting aspects of visual perception can be discovered using restricted versions of real visualization systems. It is argued that the perception of correlation in scatterplots is far from unique in this regard; a considerable number of these “fruit flies” exist, many of which are likely to cast new light on the intelligence of visual perception.

12:27 pm Where do people look on data visualizations?

Speaker: Aude Oliva, Massachusetts Institute of Technology

Additional Author: Zoya Bylinskii, MIT

What guides a viewer’s attention when she catches a glimpse of a data visualization? What happens when the viewer studies the visualization more carefully, to complete a cognitively-demanding task? In this talk, I will discuss the limitations of computational saliency models for predicting eye fixations on data visualizations (Bylinskii et al., 2017). I will present perception and cognition experiments to measure where people look in visualizations during encoding to, and retrieval from, memory (Borkin, Bylinskii, et al., 2016). Motivated by clues that eye fixations give about higher-level cognitive processes like memory, we sought a way to crowdsource attention patterns at scale. I will introduce BubbleView, our mouse-contingent interface to approximate eye tracking (Kim, Bylinskii, et al., 2017). BubbleView presents participants with blurred visualizations and allows them to click to expose “bubble” regions at full resolution. We show that up to 90% of eye fixations on data visualizations can be accounted for by the BubbleView clicks of online participants completing a description task. Armed with a tool to efficiently and cheaply collect attention patterns on images, which we call “image importance” to distinguish from “saliency”, we collected BubbleView clicks for thousands of visualizations and graphic designs to train computational models (Bylinskii et al., 2017). Our models run in real-time to predict image importance on new images. This talk will demonstrate that our models of attention for natural images do not transfer to data visualizations, and that using data visualizations as stimuli for perception studies can open up fruitful new research directions.

12:53 pm Segmentation, structure, and shape perception in data visualizations

Speaker: Steven Franconeri, Northwestern University

The human visual system evolved and develops to perceive scenes, faces, and objects in the natural world, and this is where vision scientists justly focus their research. But humans have adapted that system to process artificial worlds on paper and screens, including data visualizations. I’ll demonstrate two examples of how studying the visual system within such worlds can provide vital cross-pollination for our basic research. First a complex line or bar graph can be alternatively powerful, or vexing, for students and scientists. What is the suite of our available tools for extracting the patterns within it? Our existing research is a great start: I’ll show how the commonly encountered ‘magical number 4’ (Choo & Franconeri, 2013) limits processing capacity, and how the literature on shape silhouette perception could predict how we segment them. But even more questions are raised: what is our internal representation of the ‘shape’ of data – what types of changes to the data can we notice, and what changes would leave us blind? Second, artificial displays require that we recognize relationships among objects (Lovett & Franconeri, 2017), as when you quickly extract two main effects and an interaction from a 2x2 bar graph. We can begin to explain these feats through multifocal attention or ensemble processing, but soon fall short. I will show how these real-world tasks inspire new research on relational perception, highlighting eyetracking work that reveals multiple visual tools for extracting relations based on global shape vs. contrasts between separate objects.

1:19 pm Color Perception in Data Visualizations

Speaker: Danielle Albers Szafir, University of Colorado Boulder

Many data visualizations use color to convey values. These visualizations commonly rely on vision science research to match important properties of data to colors, ensuring that people can, for example, identify differences between values, select data subsets, or match values against a legend. Applying vision research to color mappings also creates new questions for vision science. In this talk, I will discuss several studies that address knowledge gaps in color perception raised through visualization, focusing on color appearance, lightness constancy, and ensemble coding. First, conventional color appearance models assume colors are applied to 2° or 10° uniformly-shaped patches; however, visualizations map colors to small shapes (often less than 0.5°) that vary in their size and geometry (e.g., bar graphs, line charts, or maps), degrading difference perceptions inversely with a shape's geometric properties (Szafir, 2018). Second, many 3D visualizations embed data along surfaces where shadows may obscure data, requiring lightness constancy to accurately resolve values. Synthetic rendering techniques used to improve interaction or emphasize aspects of surface structure manipulate constancy, influencing people's abilities to interpret shadowed colors (Szafir, Sarikaya, & Gleicher, 2016). Finally, visualizations frequently require ensemble coding of large collections of values (Szafir et al., 2016). Accuracy differences between different visualizations for value identification (e.g., extrema) and summary tasks (e.g., mean) suggest differences in ensemble processing for color and position (Albers, Correll, & Gleicher, 2014). I will close by discussing open challenges for color perception arising from visualization design, use, and interpretation.

S3 Prediction in perception and action

Friday, May 18, 2018, 2:30 - 4:30 pm, Talk Room 1

Organizer: Katja Fiehler, Department of Psychology and Sports Science, Giessen University, Giessen, Germany

Presenters: Mary Hayhoe, Miriam Spering, Cristina de la Malla, Katja Fiehler, Kathleen Cullen

Prediction is an essential mechanism enabling humans to prepare for future events. This is especially important in a dynamically changing world, which requires rapid and accurate responses to external stimuli. Predictive mechanisms work on different time scales and at various information processing stages. They allow us to anticipate the future state both of the environment and ourselves. They are instrumental to compensate for noise and delays in the transmission of neural signals and allow us to distinguish external events from the sensory consequences of our own actions. While it is unquestionable that predictions play a fundamental role in perception and action, their underlying mechanisms and neural basis are still poorly understood. The goal of this symposium is to integrate recent findings from psychophysics, sensorimotor control, and electrophysiology to update our current understanding of predictive mechanisms in different sensory and motor systems. It brings together a group of leading scientists at different stages in their career who all have made important contributions to this topic. Two prime examples of predictive processes are considered: when interacting with moving stimuli and during self-generated movements. The first two talks from Hayhoe and Spering will focus on the oculomotor system which provides an excellent model for examining predictive behavior. They will show that smooth pursuit and saccadic eye movements significantly contribute to sucessful predictions of future visual events. Moreover, Hayhoe will provide examples for recent advances in the use of virtual reality (VR) techniques to study predictive eye movements in more naturalistic situations with unrestrained head and body movements. De la Malla will extend these findings to the hand movement system by examining interceptive manual movements. She will conclude that predictions are continuously updated and combined with online visual information to optimize behavior. The last two talks from Fiehler and Cullen will take a different perspective by considering predictions during self-generated movements. Such predictive mechanims have been associated with a forward model that predicts the sensory consequences of our own actions and cancels the respective sensory reafferences. Fiehler will focus on such cancellation mechanisms and present recent findings on tactile suppression during hand movements. Based on electrophysiological studies on self-motion in monkeys, Cullen will finally answer where and how the brain compares expected and actual sensory feedback. In sum, this symposium targets the general VSS audience and aims to provide a novel and comprehensive view on predictive mechanisms in perception and action spanning from behavior to neurons and from strictly laboratory tasks to (virtual) real world scenarios.

2:32 pm Predictive eye movements in natural vision

Speaker: Mary Hayhoe, Center for Perceptual Systems, University of Texas Austin, USA

Natural behavior can be described as a sequence of sensory motor decisions that serve behavioral goals. To make action decisions the visual system must estimate current world state. However, sensory-motor delays present a problem to a reactive organism in a dynamically changing environment. Consequently it is advantageous to predict future state as well. This requires some kind of experience-based model of how the current state is likely to change over time. It is commonly accepted that the proprioceptive consequences of a planned movement are predicted ahead of time using stored internal models of the body's dynamics. It is also commonly assumed that prediction is a fundamental aspect of visual perception, but the existence of visual prediction and the particular mechanisms underlying such prediction are unclear. Some of the best evidence for prediction in vision comes from the oculomotor system. In this case, both smooth pursuit and saccadic eye movements reveal prediction of the future visual stimulus. I will review evidence for prediction in interception actions in both real and virtual environments. Subjects make accurate predictions of visual target motion, even when targets follow trajectories determined by the complex dynamics of physical interactions, and the head and body are unrestrained. These predictions appear to be used in common by both eye and arm movements. Predictive eye movements reveal that the observer's best guess at the future state of the environment is based on image data in combination with representations that reflect learnt statistical properties of dynamic visual environments.

2:54 pm Smooth pursuit eye movements as a model of visual prediction

Speaker: Miriam Spering, Department of Ophthalmology & Visual Sciences, University of British Columbia, Vancouver, Canada

Real-world movements, ranging from intercepting prey to hitting a ball, require rapid prediction of an object's trajectory from a brief glance at its motion. The decision whether, when and where to intercept is based on the integration of current visual evidence, such as the perception of a ball's direction, spin and speed. However, perception and decision-making are also strongly influenced by past sensory experience. We use smooth pursuit eye movements as a model system to investigate how the brain integrates sensory evidence with past experience. This type of eye movement provides a continuous read-out of information processing while humans look at a moving object and make decisions about whether and how to interact with it. I will present results from two different series of studies: the first utilizes anticipatory pursuit as a means to understand the temporal dynamics of prediction, and probes the modulatory role of expectations based on past experience. The other reveals the benefit of smooth pursuit itself, in tasks that require the prediction of object trajec-

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tories for perceptual estimation and manual interception. I will conclude that pursuit is both an excellent model system for prediction, and an important contributor to successful prediction of object motion.

3:16 pm Prediction in interceptive hand movements

Speaker: Cristina de la Malla, Department of Human Movement Sciences, Vrije Universiteit Amsterdam, The Netherlands

Intercepting a moving target requires spatial and temporal precision: the target and the hand need to be at the same position at the same time. Since both the target and the hand move, we cannot just aim for the target's current position, but need to predict where the target will be by the time we reach it. We normally continuously track targets with our gaze, unless the characteristics of the task or of the target make it impossible to do so. Then, we make saccades and direct our movements towards specific locations where we predict the target will be in the future. If the precise location at which one is to hit the target only becomes evident as the target approaches the interception area, the gaze, head and hand movements towards this area are delayed due to not having the possibility of predicting the target future position. Predictions are continuously updated and combined with online visual information to optimize our actions: the less predictable the target's motion, the more we have to rely on online visual information to guide our hand to intercept it. Updating predictions with online information allow to correct for any mismatch between the predicted target position and the hand position during an on-going movement, but any perceptual error that is still present at the last moment at which we can update our prediction will result in an equivalent interception error.

3:38 pm Somatosensory predictions in reaching

Speaker: Katja Fiehler, Department of Psychology and Sports Science, Giessen University, Giessen, Germany

Movement planning and execution lead to changes in somatosensory perception. For example, tactile stimuli on a moving compared to a resting limb are typically perceived as weaker and later in time. This phenomenon is termed tactile suppression and has been linked to a forward model mechanism which predicts the sensory consequences of the self-generated action and as a result discounts the respective sensory reafferences. As tactile suppression is also evident in passive hand movements, both predictive and postdictive mechanisms may be involved. However, its functional role is still widely unknown. It has been proposed that tactile suppression prevents sensory overload due to the large amount of afferent information generated during movement and therefore facilitates processing of external sensory events. However, if tactile feedback from the moving limb is needed to gain information, e.g. at the fingers involved in grasping, tactile sensitivity is less strongly reduced. In the talk, I will present recent results from a series of psychophysical experiments that show that tactile sensitivity is dynamically modulated during the course of the reaching movement depending on the reach goal and the predicted movement consequences. These results provide first evidence that tactile suppression may indeed free capacities to process other, movement-relevant somatosensory signals. Moreover, the observed perceptual changes were associated with adjustments in the motor system suggesting a close coupling of predictive mechanisms in perception and action.

4:00 pm Prediction during self-motion: the primate cerebellum selectively encodes unexpected vestibular information

Speaker: Kathleen Cullen, Department of Physiology, McGill University, Montréal, Québec, Canada

A prevailing view is that the cerebellum is the site of a forward model that predicts the expected sensory consequences of self-generated action. Changes in motor apparatus and/or environment will cause a mismatch between the cerebellum's prediction and the actual resulting sensory stimulation. This mismatch - the 'sensory prediction error,' - is thought to be vital for updating both the forward model and motor program during motor learning to ensure that sensory-motor pathways remain calibrated. However, where and how the brain compares expected and actual sensory feedback was unknown. In this talk, I will first review experiments that focused on a relatively simple sensory-motor pathway with a well-described organization to gain insight into the computations that drive motor learning. Specifically, the most medial of the deep cerebellar nuclei (rostral fastigial nucleus), constitutes a major output target of the cerebellar cortex and in turn sends strong projections to the vestibular nuclei, reticular formation, and spinal cord to generate reflexes that ensure accurate posture and balance. Trial by trial analysis of these neurons in a motor learning task revealed the output of a computation in which the brain selectively encodes unexpected self-motion (vestibular information). This selectively enables both the i) rapid suppression of descending reflexive commands during voluntary movements and ii) rapid updating of motor programs in the face of changes to either the motor apparatus or external environment. I will then consider the implications of these findings regarding our recent work on the thalamo-cortical processing of vestibular information.

S4 When seeing becomes knowing: Memory in the form perception pathway

Friday, May 18, 2018, 2:30 - 4:30 pm, Talk Room 2

Organizer: Caitlin Mullin, Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of the Technology

Presenters: Wilma Bainbridge, Timothy Brady, Gabriel Kreiman, Nicole Rust, Morgan Barense, Nicholas Turk-Browne

Classic accounts of how the brain sees and remembers largely describes vision and memory as distinct systems, where information about the content of a scene is processed in the ventral visual stream (VVS) and our memories of scenes past are processed by independent structures in the Medial Temporal Lobe (MTL). However, more recent work has begun to challenge this view by demonstrating interactions and dependencies between visual perception and memory at nearly every stage of the visual processing hierarchy. In this symposium, we will present a series of cutting edge behavioural and neuroscience studies that showcase an array of crossmethodological approaches (psychophysics, fMRI, MEG, single unit recording in monkeys, human E-CoG) to establish that perception and memory are part of a shared, bidirectional, interactive network. Our symposium will begin with Caitlin Mullin providing an overview of the contemporary problems associated with the traditional memory/perception framework. Next, Wilma Bainbridge will describe the factors that give rise to image memorability. Tim Brady will follow with a description of how the limits of encoding affect visual memory storage and retrieval. Gabriel Kreiman will focus on how our brains interpret visual images that we have never encountered before by drawing on memory systems. Nicole Rust will present evidence that one of the same VVS brain areas implicated in visual object recognition, monkey IT cortex, also reflects visual memory signals that are well-aligned with behavioral reports of remembering and forgetting. Morgan Barense will describe the transformation between the neural coding of low level perceptual to high level conceptual features in one brain area that lies within the MTL, perirhinal cortex. Finally, Nick Turk-Browne will describe the role of the hippocampus in generating expectations that work in a top-down manner to influence our perceptions. Our symposium will culminate with a discussion focused on how we can develop an integrative framework that provides a full account of the interactions between vision and memory, including extending state-of-the art computational models of visual processing to also incorporate visual memory, as well as understanding how dysfunction in the interactions between vision and memory systems lead to memory disorders. The findings and resulting discussions presented in this symposium will be targeted broadly and will reveal important considerations for anyone, at any level of their career (student, postdoc or faculty), interested in the interactions between visual perception and memory.

2:40 pm Memorability – predicting memory from visual information, and measuring visual information from memory

Speaker: Wilma Bainbridge, National Institute of Mental Health

While much of memory research focuses on the memory behavior of individual participants, little memory work has looked at the visual attributes of the stimulus that influence future memory. However, in recent work, we have found that there are surprising consistencies to the images people remember and forget, and that the stimulus ultimately plays a large part in predicting later memory behavior. This consistency in performance can then be measured as a perceptual property of any stimulus, which we call memorability. Memorability can be easily measured in the stimuli of any experiment, and thus can be used to determine the degree previously found effects could be explained by the stimulus. I will present an example where we find separate neural patterns sensitive to stimulus memorability and individual memory performance, through re-analyzing the data and stimuli from a previously published fMRI memory retrieval experiment (Rissman et al., 2010). I will also show how memorability can be easily taken into account when designing experiments to ask fundamental questions about memory, such as – are there differences between the types of images people can recognize versus the types of images people can recall? I will present ways for experimenters to easily measure or control for memorability in their own experiments, and also some new ways quantify the visual information existing within a memory.

2:55 pm The impact of perceptual encoding on subsequent visual memory

Speaker: Timothy Brady, University of California San Diego

Memory systems are traditionally associated with the end stages of the visual processing sequence: attending to a perceived object allows for object recognition; information about this recognized object is stored in working memory; and eventually this information is encoded into an abstract long-term memory representation. In this talk, I will argue that memories are not truly abstract from perception: perceptual distinctions persist in memory, and our memories are impacted by the perceptual processing that is used to create them. In particular, I will talk about evidence that suggests that both visual working memory and visual long-term memory are limited by the quality and nature of their perceptual encoding, both in terms of the precision of the memories that are formed and their structure.

3:10 pm Rapid learning of meaningful image interpretation

Speaker: Gabriel Kreiman, Harvard University

A single event of visual exposure to new information may be sufficient for interpreting and remembering an image. This rapid form of visual learning stands in stark contrast with modern state-of-the-art deep convolutional networks for vision. Such models thrive in object classification after supervised learning with a large number of training examples. The neural mechanisms subserving rapid visual learning remain largely unknown. I will discuss efforts towards unraveling the neural circuits involved in rapid learning of meaningful image interpretation in the human brain. We studied single neuron responses in human epilepsy patients to instances of single shot learning using Mooney images. Mooney images render objects in binary black and white in such a way that they can be difficult to recognize. After exposure to the corresponding grayscale image (and without any type of supervision), it becomes easier to recognize the objects in the original Mooney image. We will demonstrate a single unit signature of rapid learning in the human medial temporal lobe and provide initial steps to understand the mechanisms by which top-down inputs can rapidly orchestrate plastic changes in neuronal circuitry.

3:25 pm Beyond identification: how your brain signals whether you've seen it before

Speaker: Nicole Rust, University of Pennsylvania

Our visual memory percepts of whether we have encountered specific objects or scenes before are hypothesized to manifest as decrements in neural responses in inferotemporal cortex (IT) with stimulus repetition. To evaluate this proposal, we recorded IT neural responses as two monkeys performed variants of a single-exposure visual memory task designed to measure the rates of forgetting with time and the robustness of visual memory to a stimulus parameter known to also impact IT firing rates, image contrast. We found that a strict interpretation of the repetition suppression hypothesis could not account for the monkeys' behavior, however, a weighted linear read-out of the IT population response accurately predicted forgetting rates, reaction time patterns, individual differences in task performance and contrast invariance. Additionally, the linear weights were largely all the same-sign and consistent with repetition suppression. These results suggest that behaviorally-relevant memory information is in fact reflected in via repetition suppression in IT, but only within an IT subpopulation.

3:40 pm Understanding what we see: Integration of memory and perception in the ventral visual stream

Speaker: Morgan Barense, University of Toronto

A central assumption in most modern theories of memory is that memory and perception are functionally and anatomically segregated. For example, amnesia resulting from medial temporal lobe (MTL) lesions is traditionally considered to be a selective deficit in long-term declarative memory with no effect on perceptual processes. The work I will present offers a new perspective that supports the notion that memory and perception are inextricably intertwined, relying on shared neural representations and computational mechanisms. Specifically, we addressed this issue by comparing the neural pattern similarities among object-evoked fMRI responses with behavior-based models that independently captured the visual and conceptual similarities among these stimuli. Our results revealed evidence for distinctive coding of visual features in lateral occipital cortex, and conceptual features in the temporal pole and parahippocampal cortex. By contrast, we found evidence for integrative coding of visual and conceptual object features in the perirhinal cortex of the MTL. Taken together, our findings suggest that perirhinal cortex uniquely supports the representation of fully-specified object concepts through the integration of their visual and conceptual features.

3:55 pm Hippocampal contributions to visual learning

Speaker: Nicholas Turk-Browne, Yale University

Although the hippocampus is usually viewed as a dedicated memory system, its placement at the top of, and strong interactions with, the ventral visual pathway (and other sensory systems) suggest that it may play a role in perception. My lab has recently suggested one potential perceptual function of the hippocampus -- to learn about regularities in the environment and then to generate expectations based on these regularities that get reinstated in visual cortex to influence processing. I will talk about several of our studies using high-resolution fMRI and multivariate methods to characterize such learning and prediction.

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S5 Visual remapping: From behavior to neurons through computation

Friday, May 18, 2018, 5:00 - 7:00 pm, Talk Room 1

Organizers: James Mazer, Cell Biology & Neuroscience, Montana State University, Bozeman, MT & Fred Hamker, Chemnitz University of Technology, Chemnitz, Germany

Presenters: Julie Golomb, Patrick Cavanagh, James Bisley, James Mazer, Fred Hamker

Active vision in both humans and non-human primates depends on saccadic eye movements to accurately direct the foveal portion of the retina towards salient visual scene features. Saccades, in concert with visual attention, can faciliate efficient allocation of limited neural and computational resources in the brain during visually guided behaviors. Saccades, however, are not without consequences; saccades can dramatically alter the spatial distribution of activity in the retina several times per second. This can lead to large changes to the cortical scene representation even when the scene is static. Behaviors that depend on accurate visuomotor coordination and stable sensory (and attentional) representations in the brain, like reaching and grasping, must somehow compensate for the apparent scene changes caused by eye movements. Recent psychophysical, neurophysiological and modeling results have shed new light on the neural substrates of this compensatory process. Visual "remapping" has been identified as a putative mechanism for stabilizing visual and attentional representations across saccades. At the neuronal level, remapping occurs when neuronal receptive fields shift in anticipation of a saccade, as originally described in the lateral intraparietal area of the monkey (Duhamel et al., 1992). It has been suggested that remapping facilitates perceptual stability by bridging pre- and post-saccadic visual and attentional representations in the brain. In this symposium we will address the functional role of remapping and the specific relationship between neurophysiological remapping (a single-neuron phenomenon) and psychophysically characterized perisaccadic changes in visual perception and attentional facilitation. We propose to consider computational modeling as a potential bridge to connect these complementary lines of research. The goal of this symposium is to clarify our current understanding of physiological remapping as it occurs in different interconnected brain regions in the monkey (V4, LIP and FEF) and to address how remapping at the neuronal level can account for observed perisaccadic changes in visual perception and attentional state. Symposium participants have been drawn from three different, yet complementary, disciplines: psychophysics, neurophysiology and computational modeling. Their approaches have provided novel insights into remapping at phenomenological, functional and mechanistic levels. Remapping is currently a major area of research in all three disciplines and, while there are several common themes developing, there remains substantial debate about the degree to which remapping can account for various psychophysical phenonomena. We propose that bringing together key researchers using different approaches to discuss the implications of currently available data and models will both advance our understanding of remapping and be broad interest to VSS members (both students and faculty) across disciplines.

5:05 pm Remapping of object features: Implications of the two-stage theory of spatial remapping

Speaker: Julie Golomb, The Ohio State University, Columbus, OH

When we need to maintain spatial information across an eye movement, it is an object's location in the world, not its location on our retinas, which is generally relevant for behavior. A number of studies have demonstrated that neurons can rapidly remap visual information, sometimes even in anticipation of an eye movement, to preserve spatial stability. However, it has also been demonstrated that for a period of time after each eye movement, a "retinotopic attentional trace" still lingers at the previous retinotopic location, suggesting that remapping actually manifests in two overlapping stages, and may not be as fast or efficient as previously thought. If spatial attention is remapped imperfectly, what does this mean for feature and object perception? We have recently demonstrated that around the time of an eye movement, feature perception is distorted in striking ways, such that features from two different locations may be simultaneously bound to the same object, resulting in feature-mixing errors. We have also revealed that another behavioral signature of object-location binding, the "spatial congruency bias", is tied to retinotopic coordinates after a saccade. These results suggest that object-location binding may need to be re-established following each eye movement rather than being automatically remapped. Recent efforts from the lab are focused on linking these perceptual signatures of remapping with model-based neuroimaging, using fMRI multivoxel pattern analyses, inverted encoding models, and EEG steady-state visual evoked potentials to dynamically track both spatial and feature remapping across saccades.

5:28 pm Predicting the present: saccade based vs motion-based remapping

Speaker: Patrick Cavanagh, Glendon College, Toronto, ON and Dartmouth College, Hanover, NH

Predictive remapping alerts neurons when a target will fall into its receptive field after an upcoming saccade. This has consequences for attention which starts selecting information from the target's remapped location before the eye movement begins even though that location is not relevant to pre-saccadic processing. Thresholds are lower and information from the target's remapped and current locations may be integrated. These predictive effects for eye movements are mirrored by predictive effects for object motion, in the absence of saccades: motion-based remapping. An object's motion is used to predict its current location and as a result, we sometimes see a target far from its actual location: we see it where it should be now. However, these predictions operate differently for eye movements and for perception, establishing two distinct representations of spatial coordinates. We have begun identifying the cortical areas that carry these predictive position representations and how they may interface with memory and navigation.

5:51 pm How predictive remapping in LIP (but not FEF) might explain the illusion of perceptual stability

Speaker: James Bisley, Department of Neurobiology, David Geffen School of Medicine at UCLA, Los Angeles, California

The neurophysiology of remapping has tended to examine the latency of responses to stimuli presented around a single saccade. Using a visual foraging task, in which animals make multiple eye movements within a trial, we have examined predictive remapping in the lateral intraparietal area (LIP) and the frontal eye field (FEF) with a focus on when activity differentiates between stimuli that are brought on to the response field. We have found that the activity in LIP, but not FEF, rapidly shifts from a pre-saccadic representation to a post-saccadic representation during the period of saccadic suppression. We hypothesize that this sudden switch keeps attentional priorities of high priority locations stable across saccades and, thus, could create the illusion of perceptual stability.

6:14 pm Predictive attentional remapping in area V4 neurons

Speaker: James Mazer, Cell Biology & Neuroscience, Montana State University, Bozeman, MT

Although saccades change the distribution of neural activity throughout the visual system, visual perception and spatial attention are relatively unaffected by saccades. Studies of human observers have suggested that attentional topography in the brain is stablized across saccades by an active process that redirects attentional facilitation to the right neurons in retinotopic visual cortex. To characterize the specific neuronal mechanisms underlying this retargeting process we trained two monkeys to perform a novel behavioral task that required them to sustain attention while making guided saccades. Behavioral performance data indicate that monkeys, like humans, can sustain spatiotopic attention across saccades. Data recorded from neurons in extrastriate area V4 during task performance were used to access perisaccadic attentional dynamics. Specificially, we asked when attentional facilitation turns on or off relative to saccades and how attentional modulation changes depending on whether a saccade brings a neuron's receptive field (RF) into or out of the attended region. Our results indicate that for a substantial fraction of V4 neurons, attentional state changes begin ~100 ms before saccade onset, consistent with the timing of predictive attentional shifts in human observers measured psychophysically. In addition, although we found little evidence of classical, LIP-style spatial remapping in V4, there was a small anticipatory shift or skew of the RF in the 100ms immediately saccades detectable at the population level, although it is unclear of this effect corresponds to a shift towards the saccade endpoint or reflects a shift parallel to the saccade vector.

6:37 pm Neuro-computational models of spatial updating

Speaker: Fred Hamker, Chemnitz University of Technology, Chemnitz, Germany

I review neuro-computational models of peri-saccadic spatial perception that provide insight into the neural mechanisms of spatial updating around eye movements. Most of the experimental observations can be explained by only two different models, one involves spatial attention directed towards the saccade target and the other relies on predictive remapping and gain-fields for coordinate transformation. The latter model uses two eye related signals: a predictive corollary discharge and eye position, which updates after saccade. While spatial attention is mainly responsible for peri-saccadic compression, predictive remapping (in LIP) and gain-fields for coordinate transformation can account for the shift of briefly flashed bars in total darkness and for the increase of the threshold in peri-saccadic displacement detection. With respect to the updating of sustained spatial attention, recently, two different types were discovered. One study shows that attention lingers after saccade at the (irrelevant) retinotopic position, another shows that shortly before saccade onset, spatial attention is remapped to a position opposite to the saccade direction. I show new results which demonstrate that both observations are not contradictory and emerge through model dynamics: The lingering of attention is explained by the (late-updating) eye position signal, which establishes an attention pointer in an eye-reference frame. This reference shifts with the saccade and updates attention to the initial position only after saccade. The remapping of attention opposite to the saccade direction is explained by the corollary discharge signal, which establishes a transient eye-reference frame, anticipates the saccade and thus updates attention prior to saccade onset.

S6 Advances in temporal models of human visual cortex

Friday, May 18, 2018, 5:00 - 7:00 pm, Talk Room 2

Organizer: Jonathan Winawer, Department of Psychology and Center for Neural Science, New York University. New York, NY

Presenters: Geoffrey K. Aguirre, Christopher J. Honey, Anthony Stigliani, Jingyang Zhou

The nervous system extracts meaning from the distribution of light over space and time. Spatial vision has been a highly successful research area, and the spatial receptive field has served as a fundamental and unifying concept that spans perception, computation, and physiology. While there has also been a large interest in temporal vision, the temporal domain has lagged the spatial domain in terms of quantitative models of how signals are transformed across the visual hierarchy (with the notable exception of motion processing). In this symposium, we address the question of how multiple areas in human visual cortex encode information distributed over time. Several groups in recent years made important contributions to measuring and modeling temporal processing in human visual cortex. Some of this work shows parallels with spatial vision. For example, one important development has been the notion of a cortical hierarchy of increasingly long temporal windows, paralleling the hierarchy of spatial receptive fields (Hasson et al, 2009; Honey et al, 2012; Murray et al, 2014). A second type of study, from Geoff Aguirre's lab, has combined the tradition of repetition suppression (Grill-Spector et al, 1999) with the notion of multiple time scales across the visual pathways to develop a computational model of how sequential stimuli are encoded in multiple visual areas (Mattar et al, 2016). Finally, several groups including the Grill-Spector lab and Winawer lab have extended the tools of population receptive field models from the spatial to the temporal domain, building models that predict how multiple cortical areas respond to arbitrary temporal sequences of visual stimulation (Horiguchi et al, 2009; Stigliani and Grill-Spector, 2017; Zhou et al 2017). Across the groups, there have been some common findings, such as the general tendency toward longer periods of temporal interactions in later visual areas. However, there are also a number of challenges in considering these recent developments together. For example, can (and should) we expect the same kind of theories and models to account for temporal interactions in both early visual areas at the time-scale of tens of milliseconds, and later visual areas at the time-scale of seconds or minutes? How do temporal properties of visual areas depend on spatial aspects of the stimuli? Should we expect principles of spatial computation, such as hierarchical pooling and normalization, to transfer analogously to the temporal domain? To what extent do temporal effects depend on task? Can temporal models at the scale of large neuronal populations (functional MRI, intracranial EEG) be explained in terms of the behavior of single neurons, and should this be a goal? Through this symposium, we aim to present an integrated view of the recent literature in temporal modeling of visual cortex, with each presenter both summarizing a recent topic and answering a common set of questions. The common questions posed to each presenter will be used to assess both the progress and the limits of recent work, with the goal of crystallizing where the field might go next in this important area.

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5:10 pm Variation in Temporal Stimulus Integration Across Visual Cortex

Speaker: Geoffrey K. Aguirre, Department of Neurology, Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA

Additional Authors: Marcelo G. Mattar; Princeton Neuroscience Institute, Princeton University, Princeton, NJ; David A. Kahn, Department of Neuroscience, University of Pennsylvania, Philadelphia, Pennsylvania; Sharon L. Thompson-Schill, Department of Psychology, University of Pennsylvania, Philadelphia, Pennsylvania

Object percept is shaped by the long-term average of experience as well as immediate, comparative context. Measurements of brain activity have demonstrated corresponding neural mechanisms, including norm-based responses reflective of stored prototype representations, and adaptation induced by the immediately preceding stimulus. Our recent work examines the time-scale of integration of sensory information, and explicitly tests the idea that the apparently separate phenomena of norm-based coding and adaptation can arise from a single mechanism of sensory integration operating over varying timescales. We used functional MRI to measure neural responses from the fusiform gyrus while subjects observed a rapid stream of face stimuli. Neural activity at this cortical site was best explained by the integration of sensory experience over multiple sequential stimuli, following a decaying-exponential weighting function. While this neural activity could be mistaken for immediate neural adaptation or long-term, norm-based responses, it in fact reflected a timescale of integration intermediate to both. We then examined the timescale of sensory integration across the cortex. We found a gradient that ranged from rapid sensory integration in early visual areas, to long-term, stable representations towards higher-level, ventral-temporal cortex. These findings were replicated with a new set of face stimuli and subjects. Our results suggest that a cascade of visual areas integrate sensory experience, transforming highly adaptable responses at early stages to stable representations at higher levels.

5:35 pm Temporal Hierarchies in Human Cerebral Cortex

Speaker: Christopher J. Honey, Department of Psychological & Brain Sciences, Johns Hopkins University. Baltimore, MD

Additional Authors: Hsiang-Yun Sherry Chien, Psychological and Brain Sciences, Johns Hopkins University; Kevin Himberger, Psychological and Brain Sciences, Johns Hopkins University

Our understanding of each moment of the visual world depends on the previous moment. We make use of temporal context to segregate objects, to accumulate visual evidence, to comprehend sequences of events, and to generate predictions. Temporal integration -- the process of combining past and present information -- appears not to be restricted to specialized subregions of the brain, but is widely distributed across the cerebral cortex. In addition, temporal integration processes appear to be systematically organized into a hierarchy, with gradually greater context dependence as one moves toward higher order regions. What is the mechanistic basis of this temporal hierarchy? What are its implications for perception and learning, especially in determining the boundaries between visual events? How does temporal integration relate to the processes supporting working memory and episodic memory? After reviewing the evidence around each of these questions, I will describe a computational model of hierarchical temporal processing in the human cerebral cortex. Finally, I will describe our tests of the predictions of this model for for brain and behavior, in settings where where humans perceive and learn nested temporal structure.

6:00 pm Modeling the temporal dynamics of high-level visual cortex

Speaker: Anthony Stigliani, Department of Psychology, Stanford University, Stanford, CA

Additional Authors: Brianna Jeska, Department of Psychology, Stanford University; Kalanit Grill-Spector, Department of Psychology, Stanford University

How is temporal information processed in high-level visual cortex? To address this question, we measured cortical responses with fMRI (N = 12) to time-varying stimuli across 3 experiments using stimuli that were either transient, sustained, or contained both transient and sustained stimulation and ranged in duration from 33ms to 20s. Then we implemented a novel temporal encoding model to test how different temporal channels contribute to responses in high-level visual cortex. Different than the standard linear model, which predicts responses directly from the stimulus, the encoding approach first predicts neural responses to the stimulus with fine temporal precision and then derives fMRI responses from these neural predictions. Results show that an encoding model not only explains responses to time varying stimuli in face- and body-selective regions, but also finds differential temporal processing across high-level visual cortex. That is, we discovered that temporal processing differs both across anatomical locations as well as across regions that process different domains. Specifically, face- and body-selective regions in lateral temporal cortex (LTC) are dominated by transient responses, but face- and body-selective regions in lateral occipital cortex (LOC) and ventral temporal cortex (VTC) illustrate both sustained and transient responses. Additionally, the contribution of transient channels in body-selective regions is higher than in neighboring face-selective regions. Together, these results suggest that domain-specific regions are organized in parallel processing streams with differential temporal characteristics and provide evidence that the human visual system contains a separate lateral processing stream that is attuned to changing aspects of the visual input.

6:25 pm Dynamics of temporal summation in human visual cortex

Speaker: Jingyang Zhou, Department of Psychology, New York University. New York, NY

Additional Authors: Noah C. Benson, Psychology, New York University; Kendrick N. Kay, Center for Magnetic Resonance Research, Department of Radiology, University of Minnesota, Twin Cities; Jonathan Winawer, Psychology and Center for Neural Science, New York University

Later visual areas become increasingly tolerant to variations in image properties such as object size, location, viewpoint, and so on. This phenomenon is often modeled by a cascade of repeated processing stages in which each stage involves pooling followed by a compressive nonlinearity. One result of this sequence is that stimulus-referred measurements show increasingly large receptive fields and stronger normalization. Here, we apply a similar approach to the temporal domain. Using fMRI and intracranial potentials (ECoG), we develop a population receptive field (pRF) model for temporal sequences of visual stimulation. The model consists of linear summation followed by a time-varying divisive normalization. The same model accurately accounts for both ECoG broadband time course and fMRI amplitudes. The model parameters reveal several regularites about temporal encoding in cortex. First, higher visual areas accumulate stimulus information over a longer time period than earlier areas, analogous to the hierarchically organized spatial receptive fields. Second, we found that all visual areas sum sub-linearly in time: e.g., the response to a long stimulus is less than the response to two successive brief stimuli. Third, the degree of compression increases in later visual areas, analogous to spatial vision. Finally, based on published data, we show that our model can account for the time course of single units in macaque V1 and multiunits in humans. This indicates that for space and time, cortex uses a similar processing strategy to achieve higher-level and increasingly invariant representations of the visual world.

Saturday Morning Talks

Visual Search

Saturday, May 19, 8:15 - 9:45 am, Talk Room 1

Moderator: Karla Evans

21.11, 8:15 am **Textures as Global Signals of Abnormality in the Interpretation of Mammograms** Yelda Semizer[1](yelda.semizer@rutgers.edu), Melchi M Michel[1], Karla K Evans[2], Jeremy M Wolfe[3,4,5]; [1]Department of Psychology, Rutgers University, [2]Department of Psychology, University of York, [3]Department of Ophthalmology, Harvard Medical School, [4]Department of Radiology, Harvard Medical School, [5]Department of Surgery, Brigham and Women's Hospital

Evans et al. (2016) demonstrated that radiologists can discriminate between normal and abnormal breast tissue at a glance. To explain this ability, they suggested that radiologists might be using some "global signal" of abnormality. Our study sought to characterize these global signals as texture descriptions (i.e., a set of stationary spatial statistics) and to determine whether radiologists rely on such texture descriptions when discriminating between normal and abnormal breast tissue. We generated synthetic images representing sections of breast parenchyma using a texture synthesis algorithm (Portilla & Simoncelli, 2000) based on texture descriptions extracted from sections of mammograms confirmed via biopsy to be normal or abnormal. Because the texture descriptions of the original and synthesized sections were identical, any global statistical signals of abnormality in the original sections were also present in the synthesized sections. Radiologists completed a task that required rating the abnormality of briefly presented tissue sections. We manipulated both the type of image (original or synthesized) and the type of tissue (normal or abnormal). Abnormal patches were extracted from cancerous breasts, and contained either the pathological (lesion-present) or non-pathological (lesion-absent) tissue. In a control experiment, BI-RADS breast density judgments confirmed that synthesized sections represented the original sections in terms of breast density. When the abnormal tissue was non-pathological, radiologists seemed to rely on global texture descriptions; performance was similar across original and synthesized sections. However, when the abnormal tissue was pathological, radiologists seemed to use additional mechanisms beyond the texture description. In particular, the existence of a lesion increased the performance only for the original sections. These findings confirm that radiologists can use texture descriptions as global signals of abnormality in diagnostic tasks. Further analyses reveal the specific statistical features of the texture description that constitute the global signal.

Acknowledgement: NSF BCS-1456822

21.12, 8:30 am **Warning signals: speeding up ultra-rapid animal detection** Olivier Penacchio[1](op5@st-andrews.ac.uk), Julie M Harris[1]; [1]University of St Andrews, School of Psychology and Neurosciences

Many species in the animal kingdom use camouflage to avoid predation. By contrast, aposematic species are thought to use a strategy that makes them easier for would-be predators to spot: they adopt distinctive signals, called warning signals, to inform predators that they are unprofitable. Conspicuousness has been identified as a potential pivotal attribute of the design of warning signals, but very few studies have evaluated this proposition directly. We explored the effect of warning signals on human observers in a fast animal detection experiment. In a forced-choice design, pairs of commercially available photographs of natural scenes, only one of which pictured an animal, were presented for 20 ms on either side of a central fixation point. Target images pictured terrestrial animals, ranging from mammals to amphibians and insects in their natural environment, distractor images showed natural landscapes similarly made. Participants reported, via button press, on which side the animal appeared. The set of target images contained as many aposematic as control species. Participants were not informed of the two distinct categories before the experiment was finished. Contrast was normalised across the whole set of target and distractor images and target size was balanced between the two classes of target images. In line with previous reports (Thorpe, Fize, & Marlot, 1996; Kirchner & Thorpe, 2006), we found observers could do this task with very fast speed (median 443 ms) and accuracy (93%). Our novel finding here was that reaction times were significantly shorter (30 ms, 428 ms versus 457 ms) and detection more accurate (95.5% versus 90%) for aposematic animals, than for non-aposematic animals. Our findings demonstrate that there is something special about aposematic patterns, and that they are 'more conspicuous' in terms of their speed of detection. We do not yet know what specific image characteristics of the pattern are responsible.

Acknowledgement: This work was supported by grant number BB/N006569/1.

21.13, 8:45 am **A foveated object detector that misses giant and misplaced targets in scenes** Aditya Jonnalagadda[1](aditya_jonnalagadda@umail.ucsb.edu), Arturo Deza[2], Miguel P. Eckstein[3]; [1]Department of Electrical and Computer Engineering, University of California, Santa Barbara, [2]Program in Dynamical Neuroscience, University of California, Santa Barbara, [3]Department of Psychological and Brain Sciences, University of California, Santa Barbara

Introduction: Scene context influences human eye movements and search performance (Chen & Zelinsky, 2006). Models have utilized contextual information to predict human eye movements with real scenes (Torralba et al., 2006; Eckstein et al., 2006) or improve computer vision (Choi et al., 2012), but such models are not foveated and do not explore the scene with eye movements to generate perceptual decisions. Here, we propose a foveated object detector (Akbas & Eckstein, 2017) that utilizes object relationships to search for targets in real scenes and show a number of classic and newly reported effects of context on human eye movements and perceptual decisions. Methods: Humans and the object detector searched for a computer mouse placed at different locations on desks with distracting objects (50 % target presence). The object detector utilized a foveated visual field (Freeman & Simoncelli, 2011), retino-specific classifiers, and executed eye movements to the most likely target location (maximum a posteriori probability with inhibition of return). The model utilized context by using a separate training data set to estimate conditional probabilities of the size and location of the mouse relative to other objects in the scene and incorporated that information to make eye movements and reach decisions. Results: Both human and the foveated object detector showed similar effects: (a) Targets with inconsistent spatial scale or atypical locations within the scene were missed more often and foveated later; (b) Distractor objects (e.g. cell phone) were foveated and misclassified as the target more often when placed at the expected location of the computer mouse. A model that did not utilize context showed no human-like context effects. Conclusions: A foveated object detector with a probabilistic model of object relationships can capture contextual effects on human search with real scenes without invoking a limited resource covert attentional mechanism.

21.14, 9:00 am **Predicting Ultimate Visual Search Competency from Initial Performance** Patrick H Cox[1](patrickcox@gwu.edu), Dwight J Kravitz[1], Stephen R Mitroff[1]; [1]The George Washington University

For any task, individuals will differ from each other in initial performance, learning rate, and ultimate task competence. As such, one question is how well initial task performance relates to eventual competence? Do those who start out as the better performers remain so later? Practically, this question is especially important for visual search performance given how many professions rely on successful search (aviation security, radiology, etc.). Our previous work (Ericson, Kravitz, & Mitroff, 2017) showed the minimal unit of data (participants' response time on the first trial) could predict later success. However, while it was theoretically interesting to examine the smallest amount of data needed to predict later levels of performance, it is practically interesting to maximize classification accuracy of eventual success from initial performance. In this study we leveraged "big data" (>3.3 billion trials from >14 million unique devices) from the Airport Scanner mobile app game (Kedlin Co.) and linear classification techniques to expand beyond single trial classification methods.

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Improved prediction of highest rank achieved in the visual search based game, our proxy for ultimate visual search competence, was achieved here by: 1) examining performance metrics in addition to response time (e.g., hits and false alarms), and 2) reducing trial-by-trial variability in performance metrics across participants by controlling for factors that affect trial difficulty (e.g., number of distractors, average difficulty for specific targets, and other in-game factors). We will present data that demonstrate it is possible to use a small sample of search task performance from early in learning to predict later success with high accuracy. The data highlight that while everyone can improve at a task with experience, those who start out the best tended to remain the best. Morever, it is possible to use the initial data to classify later top and bottom performers.

Acknowledgement: Army Research Office

21.15, 9:15 am **Scene meaning and salience are suppressed during arbitrary visual search** Taylor R. Hayes[1](trhayes@ucdavis.edu), John M. Henderson[1,2]; [1]Center for Mind and Brain, University of California, Davis, [2]Department of Psychology, University of California, Davis

We have recently shown that meaning is a better predictor of overt visual attention than salience during scene memorization and aesthetic judgment tasks (Henderson & Hayes, 2017). The present study investigated whether meaning- or salience-based guidance are suppressed while performing an arbitrary visual search task. Thirty-eight participants viewed 80 real-world scenes for 12 seconds each and searched for embedded letter L targets. Half of the scenes contained 1 or 2 randomly placed letter targets and the other 40 scenes contained no targets to avoid excessive target fixations. Only the fixation data from the 40 no-target scenes were analyzed. For each scene, a fixation density map was computed across all 38 participants to summarize scene viewing behavior. A saliency map for each scene was computed using the Graph-Based Visual Saliency model (Harel, Koch, & Perona 2006). Finally, a meaning map was generated for each scene using human ratings of how informative/recognizable isolated scene regions were on a 6-point Likert scale. Scene regions were sampled using overlapping circular patches at two different spatial scales. Each unique patch was then rated 3 times by participants on Amazon Mechanical Turk (N=165) that rated a random set of 300 patches. The spatial rating maps were smoothed using interpolation and averaged together to produce a meaning map for each scene. The squared linear correlation between each scene fixation density map and the corresponding meaning and salience maps were computed. Meaning explained 18% (SD=10.8) of the variance in scene fixation density while salience explained 13% (SD=9.1). This is almost a 3-fold reduction relative to the scene memorization task and aesthetic judgment tasks of Henderson and Hayes (2017). These results suggest that scene-orthogonal task demands are capable of suppressing both meaning- and salience-based guidance during scene viewing.

Acknowledgement: Supported by the National Eye Institute (R01EY027792)

21.16, 9:30 am **Hybrid foraging meets navigation: Can augmented reality improve performance in real world search tasks?** Hayden Schill[1](hschill@bwh.harvard.edu), Farahnaz A. Wick[1,3], Matthew S. Cain[2], Jeremy M. Wolfe[3]; [1]Brigham & Women's Hospital, [2]U.S. Army, Natick Soldier Research & Development Center, [3]Harvard Medical School

Classic visual search often involves a single target in artificial, static displays. However, real world search tasks can involve looking for multiple instances of multiple types of targets (hybrid foraging) among distractors. In this study, we investigated how the human "search engine" performs hybrid foraging while actively navigating through a 3D city terrain. We also investigate whether augmented reality, in the form of navigational cues, provide a benefit in this kind of complex, real-world search. In this videogame-style task, observers memorized either 4, 8, or 16 target objects and were given two competing tasks: navigate to the endpoint with a time deadline and collect as many targets as possible. Navigation cues were either an 'arrow' presented at corners of streets directing them to the endpoint, or a 'waypoint' cue, numerically indicating the distance to the endpoint, with the number decreasing if they moved in the correct direction. In our analysis, we focused on the cost of memory load, type of navigational cues, and the pattern of target selection (rate at which targets were picked, collecting multiple instances of a target type or 'runs'). We found that navigational cues hindered search performance. Observers who were not given any navigational cues picked up more targets than those given navigational cues (None: 0.492 targets/second, Arrow: 0.467, Waypoint: 0.393, $p < .02$). The rate at which targets were picked decreased as memory load increased ($p < .01$) and when navigational cues were provided ($p < .01$). The number of runs decreased significantly as the memory load increased but was not significantly different between the navigation conditions. These results provide a first look into a complex search task in a dynamic display and how the human search engine copes with navigational cues while performing visual search.

Perceptual Learning: Basic

Saturday, May 19, 8:15 - 9:45 am, Talk Room 2

Moderator: Chaz Firestone

21.21, 8:15 am **Endogenous spatial attention facilitates transfer of learning to untrained locations** Ian Donovan[1](ian.donovan@nyu.edu), Marisa Carrasco[1, 2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Background. Location specificity is a hallmark of perceptual learning: performance improvements are usually confined to trained retinal locations. Previously, we showed that training with valid exogenous cues facilitates transfer of learning to untrained locations in an orientation discrimination task, increasing asymptotic performance at high contrasts at both trained and untrained locations.Here, we investigated the yet-unknown influence of endogenous spatial attention on perceptual learning and characterized its influence on location specificity. Method. Before and after training, participants were tested on an orientation discrimination task at four peripheral locations. Participants trained for 3 sessions at two locations. Targets were Gabors of varying contrast (2-64%) oriented clockwise or counter-clockwise relative to vertical. The Attention group (n=12) received 100% valid endogenous spatial pre-cues which instructed participants to pay attention to one of the trained locations on each trial. The Neutral group (n=12) received uninformative cues, which indicated the two locations where a target may appear. During the Pre- and Post-Tests, all participants received neutral cues. Learning was assessed at the Trained and Untrained locations separately by comparing performance on the Post-Test to that of the Pre-Test. Results. In the Attention group, thresholds improved between the Pre- and Post-Tests for both the Trained and Untrained locations. In the Neutral group, thresholds improved for the Trained locations, but not for the Untrained locations. Model comparisons confirmed that changes in only threshold accounted for learning at the Trained location of the Neutral group, and Trained as well as Untrained locations in the Attention group. Conclusions. Training with endogenous attention, similar to exogenous attention, enables transfer to untrained locations. Unlike exogenous attention, which mostly influences the asymptote of the contrast sensitivity function, endogenous attention influences the threshold, suggesting distinct mechanisms for the influence of endogenous and exogenous attention on perceptual learning and location transfer.

Acknowledgement: NIHRO1-EY016200

21.22, 8:30 am **Mapping the effects of stimulus history on perception** Nikos Gekas[1](nikos.gekas@outlook.com), Pascal Mamassian[1]; [1]Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, PSL Research University, CNRS, 75005 Paris, France

There is an ongoing debate on the effects of stimulus history on perception. Recent studies have shown that repeated perceptual decisions to similar stimuli lead to contextual effects, correlated both negatively with the past (negative aftereffects) and positively (serial dependence), sometimes at the same time (Chopin and Mamassian, Current Biology, 2012; Fritsche et al., Current Biology, 2017). However, less attention has been given to understanding how these effects evolve for stimuli further in the past. This task can be challenging because the effect is weak and difficult to dissociate with that of the very recent history. Here, we design a novel psychophysical paradigm to specifically target the influence of stimulus statistics at different points in the past. Observers are presented with oriented Gabor patches from a set number of orientations, randomly interleaved, and are asked to judge whether the orientation of each patch is clockwise or counter-clockwise from a reference orientation. For a specific orientation (targeted orientation), we manipulate the presentation of orientations at a specific point in the past, e.g. K trials in the past, while balancing the orientations shown in the immediate past. We are then able to measure the shift in the perception of the targeted orientation compared to a baseline measurement. By repeating the experiment for different values of K, we map the effect of the stimulus history independently of the immediate history. Our results suggest that stimulus regularities can have an influence on the current percept even when distant in time. Furthermore, due to the careful balancing and the lack of autocorrelations in the statistics of the stimulus, we can show that our findings represent a genuine effect of adaptation to the stimulus statistics and not an artefact of the stimulus pattern.

21.23, 8:45 am **Statistical learning generates implicit conjunctive predictions** Ru Qi Yu[1](ruqiyu@psych.ubc.ca), Jiaying Zhao[2]; [1]Department of Psychology, University of British Columbia, [2]Department of Psychology, Institute for Resources, Environment and Sustainability, University of British Columbia

The visual system readily detects statistical relationships where the presence of an object predicts a specific outcome. What is less known is how the visual system generates predictions when multiple objects predicting different outcomes are present simultaneously. Here we examine the rules with which predictions are made in the presence of two objects that are associated with two distinct outcomes. In a visual search paradigm, participants first viewed one color dot and then searched for a target (a rotated T) in an array during the exposure phase. Each color predicted a specific location of the target. For example, after a blue dot the target would appear only in the top half of the array; and after a red dot the target would appear only in the left half of the array. The question is: Where was the target expected to appear when both the blue dot and the red dot were present? A conjunctive prediction would mean that the target was expected to appear in the top left quadrant of the array, whereas a disjunctive prediction would mean that the target was expected to appear in the top half or the left half of the array. Importantly at the test phase when both dots were present, the target was equally likely to appear in any half of the array. We found that participants were reliably faster to find the target when it appeared in the conjunctive quadrant. This was true even if participants were not consciously aware of the association between the color dots and target locations during debriefing. This effect was equally strong whether participants implicitly learned the association or were explicitly told about the association. The results suggest that in the presence of multiple predictors, statistical learning generates implicit expectations about the outcomes in a conjunctive fashion.

21.24, 9:00 am **Modeling the scientist in the crib** Nick Haber[1](nhaber@stanford.edu), Damian Mrowca[1], Li Fei-Fei[1], Daniel L.K. Yamins[1]; [1]Stanford University

Deep convolutional neural networks, when trained on difficult supervised tasks such as object classification on large datasets, have shown the remarkable property of learning general representations useful for many other tasks and predictive of responses in the ventral visual stream. These successes have led to the pursuit of tasks that are able to generate a visual backbone in developmentally-realistic ways. Yet large gaps remain to be filled. -Lack of supervision Training must happen without large amounts of manually-labeled data. -Interaction and agency The developmental behavioral literature intertwines such developments with interaction with the world, explaining rich behaviors through this training. We built a simulated environment based on a game engine that provides 3D visual stimuli and allows for agent interactions with different types of objects. In this, we have an artificial agent gather experience, and with this experience, train a world model of self-supervised problems involving future, ego motion, and force predictions. We simultaneously train a model of future loss of the dynamical model. We execute an action policy determined by this predictive model that learns to focus its attention on what is interesting --- interaction with an object --- without explicitly encoding the notion of an object in the input. The policy adopts behaviors to put an object in view, approach it, and keep it in view. This leads to data collection that is more adversarial to the world model, allowing it to reach performance that a model trained on data through a random policy does not reach. The backbone developed is able to generalize to object localization through the training of a simple readout model without the backbone having been exposed to the true values of this problem. This represents first steps towards ecologically-realistic training of a vision system through an interactive, embodied process.

Acknowledgement: The Walter V. and Idun Berry Postdoctoral Fellowship Program

21.25, 9:15 am **Inducing Neural Plasticity and Perceptual Similarity via Real-Time fMRI Neurofeedback** Marius Cătălin Iordan[1](mci@princeton.edu), Victoria J. H. Ritvo[1], Kenneth A. Norman[1], Nicholas B. Turk-Browne[1,2], Jonathan D. Cohen[1]; [1]Princeton Neuroscience Institute & Psychology Department, Princeton University, [2]Psychology Department, Yale University

Information about visual categories is widely available across the brain (Haxby et al. 2001) and these representations can be modulated by both explicit learning (Hammer & Sloutsky 2016) and implicit neurofeedback training (Jackson-Hanen et al. SfN 2014). However, the causal link between the neural representation of categories and their perception remains unclear. To address this question, we seek to induce neural plasticity of visual representations via real-time fMRI neurofeedback (deBettencourt et al. 2015) and test whether this drives categorical perception. We hypothesize that increasing neural separation between categories should also differentiate the categories perceptually. To this end, we seek to use neurofeedback to emphasize non-overlapping (unique) features and suppress overlapping (shared) features of novel abstract visual categories. To do so, we constructed a stimulus space of complex artificial shapes that vary along multiple dimensions simultaneously (Op de Beeck et al. 2001). Extensive behavioral norming (n=750) suggests that each stimulus dimension is perceived in an equivalently graded manner, as are manipulations of the space along multiple dimensions simultaneously. Additionally, we developed a novel approach (KL-Evidence) for computing the neurofeedback provided to differentiate categories, based on mutual information between the distributions of neural responses they elicit. Simulations showed that our method accurately pinpoints non-overlapping features to be emphasized during neurofeedback to induce desired plasticity. We'll present preliminary results from an fMRI study in which we use this feedback method to induce plasticity in representations elicited by arbitrary categories from the stimulus space. By collecting perceptual similarity ratings pre- and post-feedback, we examine a potential causal role for these induced neural representations in similarity judgments. More generally, the approaches we develop for inducing neural plasticity may open up a new platform to investigate and understand human learning with fMRI.

Acknowledgement: John Templeton Foundation, Intel Corporation, NIH Grant R01 MH069456

21.26, 9:30 am **Prior repulsion: "Anti-Bayesian" updating in visual cognition** Steven Gross[1,2,3](sgross11@jhu.edu), Chaz Firestone[3]; [1]Department of Philosophy, Johns Hopkins University, [2]Department of Cognitive Science, Johns Hopkins University, [3]Department of Psychological and Brain Sciences, Johns Hopkins University

How do prior assumptions about uncertain data inform our inferences about those data? Increasingly, such inferences are thought to work in the mind the way they should work in principle — with our interpretations of uncertain evidence being nudged towards our prior hypotheses in a "rational" manner approximating Bayesian inference. By contrast, here we explore a class of phenomena that appear to defy such normative principles of inference: Whereas inferences about new data are typically attracted toward prior expectations, we demonstrate how inferences may also be repelled away from prior expectations. In seven experiments, subjects briefly saw arrays of two spatially intermixed sets of objects (e.g. several dozen squares and circles). Over the course of the session, subjects learned that one set was typically more numerous than the other — for example, that there are typically more squares than circles. Surprisingly, upon forming the expectation that they would continue to see more squares, subjects who were then shown an equal number of squares and circles (such that it was unclear exactly which had more) judged the circles to be more numerous, seemingly adjusting their inferences away from their prior hypothesis about what they would see. Six follow-up experiments show how this effect is not explained by low-level sensory adaptation (occurring even when various sensory dimensions are equated), generalizes to many kinds of stimuli (including colors, and configural-

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ly-defined letters), and is robust to different measures (not only forced-choice ["which has more?"] but also precise enumeration ["how many are there?"]). We discuss how this "expectation contrast" effect is a genuine case of adjusting "away" from our priors, in seeming defiance of normative principles of inference. We also point to a broader class of phenomena that may behave in this way, and explore their consequences for Bayesian models of perception and cognition.

Acknowledgement: JHU Science of Learning Institute

Attention: Features and objects

Saturday, May 19, 10:45 am - 12:30 pm, Talk Room 1

Moderator: Julie Golomb

22.11, 10:45 am **The Effect of Resolution on Guiding Visual Selective Attention is Contingent Upon Task-Relevance** Jared J Peterson[1](jaredpeterson@k-state.edu), Lester C Loschky[1]; [1]Psychological Sciences, Arts and Sciences, Kansas State University

How does resolution guide attention? Previous studies have shown that unique clarity captures attention (Enns & MacDonald, 2013; Loschky & McConkie, 2002; Peterson & Loschky, submitted; Smith & Tadmor, 2012). But, what about blur? Peterson et al. (2017) found unique blur weakly repelled attention towards nearby clarity, whereas unique clarity strongly captured attention. Are these results explainable by resolution being a search asymmetry? If resolution is a search asymmetry, then making resolution task-relevant should replicate Peterson et al.'s asymmetric findings. However, if both blur and clarity can be selected for and used to efficiently guide attention, then resolution is not a search asymmetry, but instead depends upon its task-relevance. Experiment 1 manipulated task relevance in a rotated L versus T visual search task while measuring eye movements and reaction times. Resolution's task-relevance was manipulated with instructions (Use Blur, Use Clarity, Do Not Use Unique Blur or Clarity, and No Instructions) and probability (in a set size of 6, Task-relevant resolution singleton at target 67% (4/6), Task-irrelevant resolution singleton at target 17% (1/6) = chance). The results showed unique blur was strongly selected for when task-relevant, but weakly repelled attention toward nearby clarity when task-irrelevant. Experiment 2 asked if resolution is preattentively available when task-relevant. In two conditions, participants either searched for a blurred or clear T, amongst T distractors of the opposite resolution with set sizes 2, 4, and 8. The target present RT x Set Size search slopes for both blur and clarity were < 1 msec/item, suggesting that both are processed preattentively and resolution is not a search asymmetry. Overall, the results suggest resolution's influence on attention is contingent upon its task-relevance. When relevant, both blur and clarity are efficiently selected for and strongly guide attention. When task-irrelevant, unique clarity strongly captures attention, while unique blur weakly repels attention towards nearby clarity.

22.12, 11:00 am **Oscillatory Dynamics in Widespread Cortical Networks During Feature-Based Attention: Coupling Across and Between Frequencies** Nina N Thigpen[1](nthigpen@ufl.edu), Amy Trongnetrpunya[1], Jean Cibula[1], Aysegul Gunduz[1], Forest Gruss[1], Ke Bo[1], Enrico Opri[1], Mingzhou Ding[1], Andreas Keil[1]; [1]University of Florida

Feature-based attention is essential for quickly and accurately selecting information from the environment for further, in-depth processing. The animal model provides a strong understanding of the neural correlates of feature-based selective attention from the level of single-cell recordings to large-scale networks. Here, we aim to translate these findings from the animal model to human observers, using electrocorticogram (ECoG) data collected from five patients undergoing evaluation for chronic epilepsy, directly from the left frontal, orbitofrontal, anterior and posterior inferior temporal (IT) cortex. Participants completed a feature-based selective attention task, where they viewed a series of Gabor patches that were either a match or a distractor, relative to a target stimulus. Distractors could differ from the target along three feature dimensions: color (red/green), orientation (left/right), and shape (oval/circle). Results suggest that target features prompt robust amplification of oscillatory gamma and theta activity, in most of the recorded locations. The latency of these changes was consistent with re-entrant bias signals, in which attention effects occur earlier at frontal sites and later (>200 ms) at posterior sites. Gamma power in the inferior temporal cortex showed a parametric reduction as a function of similarity with the target, consistent with inhibitory interactions between similar feature conjunctions. Notably, IT areas showed interference, which varied parametrically with confusability. This suggests that feature conjunctions are represented in IT, and that similar conjunctions inhibit each other. Although evidence for strong signaling was found from frontal to IT cortex from a granger causality analysis, the suppressive interactions in IT were not inherited from frontal locations. Together, the findings support a model of block-wise biasing of target features from frontal areas, aided by sharpening through local inhibitory interactions.

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22.13, 11:15 am **The neural dynamics of category-based attention** Emily J Ward[1](amyunimus@gmail.com), Floris P de Lange[2]; [1]Department of Psychology, University of Wisconsin-Madison, [2]Donders Institute for Brain, Cognition and Behaviour, Radboud University

Beyond attending to locations, features, and simple objects, it seems as if we can attend to visual categories, such as "cars" or "beaches". This hints that attentional tuning may extend to categorical information. We used magnetoencephalography (MEG) to investigated the neural dynamics of category-based attention. Participants (n=24) viewed rapid serial visual presentation (RSVP) streams consisting of six images (100ms each) from eight categories. Participants reported the presence or absence of a target image. On each trial, the target category was 1) cued before the RSVP [precue], 2) cued after the RSVP [postcue], or 3) not cued. Consistent with previous research (e.g. Potter & Hagman, 2015), performance was above chance for both pre- and post-cued trials, with a strong advantage for precues vs. postcues: participants were more accurate ($p< 0.001$) and faster ($p< 0.001$) to detect targets when they had seen a cue before the RSVP. This suggests that a cue to attend to a particular category facilitates its processing at some level. To determine if this facilitation occurs at the earliest stages of visual processing, we used pattern classification to measure category information across the timecourse of each trial. We used trial-by-trial amplitude in 41 occipital MEG channels as features for classification. During the RSVP, not only could we decode the category of the target (17.5% [chance=12.5%], $p< 0.001$), but we could also decode the category of each individual distractor image (18-20%, ps< 0.001). Of these measures, target category decoding was greater for correct than incorrect trials ($p< 0.01$), but target classification based on MEG signals was not influenced by the presence of a cue. Thus, early visual responses contain information about both relevant and irrelevant categories, and that the fidelity of target representation is linked to performance. However, cueing does not appear to affect categorical information in early visual processing.

22.14, 11:30 am **Attentional Selection of Multiple Correlation Ensembles** Madison Elliott[1](maelliott1010@gmail.com), Ronald Rensink[1]; [1]The University of British Columbia

Our visual system rapidly extracts ensembles to help us understand our environment (Haberman & Whitney, 2012). However, it is not yet understood how multiple ensemble dimensions are used, or how attention can select one ensemble over another. As a first step, we investigated feature selection in attention for multi-dimensional ensembles. Specifically, we examined whether increasing featural differences, which aids perceptual grouping (Moore & Egeth, 1997), would boost selectivity for one ensemble over another. The perception of correlation in scatterplots appears to be an ensemble process (Rensink, 2017), and adding an irrelevant set of data points causes interference (Elliott & Rensink, VSS 2016; 2017). To investigate this more thoroughly, observers performed a correlation discrimination task for scatterplots containing both a "target" ensemble and an irrelevant "distractor" ensemble (Elliott & Rensink, VSS 2017) where target ensembles were distinguished by the color, shape, or color and shape combinations of their elements. Both tasks used ΔE from Szafir (2017) to create a precise experimental color space that takes into account stimulus area and mark type. Distractor colors varied in equal perceptual steps along three axes: luminance, chroma, and hue, which allowed us to investigate whether individual color dimensions influenced selection. Surprisingly, performance was equally good for targets defined by differences in single features and differences in two features. These results indicate that increasing feature differences between the two ensembles does not boost discrimination performance. Moreover, contrary to work by Nagy & Sanchez (1990) on hue differences in visual search, ensemble selection was equally effective along all three color dimensions in the task. And even very small differences along any color dimension were sufficient to facilitate ensemble selection.

Acknowledgement: UBC 4 Year Doctoral Research Fellowship

22.15, 11:45 am **The attentional template shifts and sharpens in response to competition from target-similar distractors** Xinger Yu[1,2](lucayu_831@Hotmail.com), Joy J. Geng[1,2]; [1]Department of Psychology, University of California, Davis, [2]Center for Mind and Brain, University of California, Davis

Theories of attention hypothesize the existence of an "attentional template" that contains target features in memory. It is often assumed that the template contains veridical target features, but recent studies have found that the template is flexible and shifts away from anticipated distractors to increase the target-to-distractor distinctiveness. Here, we investigated if except for shifting, the target representation can also be sharpened in response to distractor competition. In two experiments, participants were instructed to search for a target colored circle among three distractors on visual search "training" trials. Separate target identification "probe" trials were interleaved to measure the target representation. On these trials observers judged whether a single colored stimulus (sampled from both sides of the target color) was the target; "Yes" responses were modeled using a split normal distribution, and taken as an estimate the target template. In Experiment 1, we found that distractor predicability resulted in observers being more likely to misidentify colors in the direction opposite to distractors as the target, compared to a control group. The predictable directionality of visual search distractors produced a shift in the target representation away from distractors. In Experiment 2, we manipulated the strength of distractor competition in addition to distractor directionality. Participants always saw distractors from one side of the target in color space, but the similarity of those distractors to the target increased gradually over 5 blocks of visual search. We found that the magnitude of shift remained constant across blocks, but there was a continuous increase in the sharpening of the template between the target and visual search distractor colors. This suggests that shifting and sharpening are two separable mechanisms that increase target's salience. Shifting occurred in response to directionality of distractor features, while sharpening occurred in response to the strength of competition from the distractors.

22.16, 12:00 pm **Object-feature binding survives dynamic shifts of spatial attention** Emma Wu Dowd[1](dowd.45@osu.edu), Julie D Golomb[1]; [1]Department of Psychology, The Ohio State University

Successful object recognition requires the binding of different visual properties (e.g., color, shape, location) into an integrated object-level representation. Theories of feature-integration propose that spatial attention is crucial for binding—but attention is rarely static, instead dynamically shifting and splitting across multiple goals and locations. What happens to object-feature binding when attention must shift or split across multiple objects with multiple features? While maintaining central fixation, participants were briefly presented with an array of four colored, oriented bars. The target bar was defined by a spatial pre-cue that remained stable (Hold) or dynamically shifted from one location to another (Shift) before array presentation. In another condition, attention was split across two simultaneously pre-cued locations (Split). Participants were instructed to reproduce both the color and orientation (i.e., joint continuous-report) of the target item; they also performed a location report to confirm the target location. Object-feature binding was measured by applying probabilistic models to the joint distribution of feature errors: Errors in recalling both features of the same object could be correlated (and thus bound together) or independent (and unbound). Across multiple experiments, splitting attention across multiple objects degraded object integrity, resulting in unbound feature errors. In contrast, rapid shifts of spatial attention maintained object integrity—even when those shifts were inadvertent. For example, on Hold trials, participants sometimes misreported the target location, indicating a lapse of spatial attention. Yet on these trials, participants reported both the color and orientation bound to that incorrectly-attended location. Moreover, converging data from a parallel line of fMRI experiments reveal that neural reconstructions reflect the features of the attended object on a trial-by-trial basis, even when attention selects the incorrect object. Together, these results emphasize the importance of a single focus of spatial attention in object-feature binding, whether that focus is stable or dynamically shifting across multiple locations.

Acknowledgement: NIH F32-EY028011 (EWD), NIH R01-EY025648 (JG), Alfred P. Sloan (JG)

22.17, 12:15 pm **Current and future goals are represented in opposite patterns in object-selective cortex** Anouk M van Loon[1,2](anouk.vanloon@gmail.com), Johannes J Fahrenfort[1,3], Christian N. L. Olivers[1,2]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, [2]Institute of Brain and Behavior Amsterdam, Vrije Universiteit Amsterdam, [3]Department of Brain and Cognition, University of Amsterdam

Previous studies have shown that only representations of currently task relevant goals can be decoded from brain activity. However, it is still unclear how and where representations of future goals are instantiated in the brain. Here, we measured fMRI of 24 human participants while on each trial we presented two real-world objects from different categories serving as targets for two consecutive visual search tasks. We manipulated the relevance of the objects with a cue that indicated which object to look for first (current), and which second (prospective). Before each search there was an eight second retention interval. We used multi-voxel pattern analysis to decode the dynamical changes in representational space of the object categories in object-selective cortex throughout the trial, as a function of current versus prospective task relevance. As predicted, we observed better category decoding for the currently relevant than for the prospectively relevant category right before the first search. However, even during search for the current target we could successfully decode the future target. When we trained the classifier on the currently relevant category and tested on the prospectively relevant category or vice versa, classification was below-chance during both searches. This indicates that current and future object categories are represented in opposite corners of the representational space. Indeed, representational similarity analyses confirmed that as a trial unfolds, object representations move from object category space (e.g. a cow) into relevance space (e.g. current target), where current and prospective targets of the same category are represented by opposite representational patterns. Taken together, our results demonstrate how the brain shields current from future targets and vice versa.

Acknowledgement: ERC Consolidator Grant 2013-CoG-615423

Spatial Vision: Modeling and physiology

Saturday, May 19, 10:45 am - 12:30 pm, Talk Room 2

Moderator: Frank Tong

22.21, 10:45 am **Similarity effects in peripheral vision: improved representation or cuing?** Dian Yu[1](dianyu2017@u.northwestern.edu), Ruth Rosenholtz[1,2]; [1]Computer Science and Artificial Intelligence Lab, MIT, [2]Brain and Cognitive Sciences, MIT

In peripheral vision, similarity grouping influences what information can be accessed: observers can better identify a target when flankers share a feature distinct from that of the target. For example, one can more readily identify a target when flankers have opposite sign of contrast. One possible explanation of this "relief from crowding" is that feature pooling occurs only within perceptual groups, presumed to lead to better representation of targets that do not group with the flankers. The similarity effect, however, may not solely derive from better representation of an oddball target. A confounding factor remains: peripheral vision is characterized by location uncertainty. Any cue to target location would aid decision-making and identification. In most studies, the item with the distinctive feature is always the target, providing a 100% reliable cue. To understand how much of similarity effects can be attributed to target location cueing vs. improved target representation, we varied the reliability of the distinctive feature as a cue to the target. In the cue-reliable block, the distinctive feature is always associated with the target. In the cue-unreliable block, either the target or one of the flankers has the distinctive feature with equal probability. As expected, we observed improved performance with dissimilar compared to similar flankers in contrast

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polarity (M=20%,n=4,p=.002), orientation (M=13%,n=8,p=.001) and spatial frequency (M=16%,n=8,p=.003). Moreover, for contrast polarity, performance on distinctive target trials was significantly higher in cue-reliable blocks (72%) compared to cue-unreliable blocks (59%) (p=.002). However, such distinction was not found for orientation (reliable=66% vs. unreliable=59%, p=.38) or spatial frequency (reliable=67% vs. unreliable=66%, p=.86). Our results show that distinctive contrast polarity reduces target location uncertainty, aiding discriminability of oddball peripheral targets. Other similarity effects may instead derive more from better representation of an oddball target rather than from cueing effects.

Acknowledgement: NSF-CRCNS

22.22, 11:00 am **Polar coordinates as the format of spatial representation in visual perception** Feitong Yang[1](ft.yang@jhu.edu), Jonathan I Flombaum[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Does perception describe locations as orthogonal distances from an origin, a Cartesian format; or does it employ Polar descriptions, a distance from the origin with angular bearings? Are these representations even distinguishable? After all, they are isomorphic: any representation in one format can be translated to the other. As inputs to template matching routines, however, they differ in terms of which templates are described linearly vs nonlinearly. We reasoned that linear templates should be more easily matched than nonlinear. We therefore replicated and extended experiments on the identification of overlapping Glass patterns. Participants recognized circular and radial patterns more easily than line patterns, consistent with the Polar coordinate hypothesis wherein circle and radial patterns have linear descriptions. We further examined the hypothesis by considering it as an explanation for Vernier acuity performance. Across a wide range of conditions, including Vernier stimuli placed on oblique axes, we found significant biases to report alignment for stimuli that are misaligned towards the circumference of the circle defined by fixation — stimuli misaligned in Cartesian terms, but aligned (i.e. linearly related) in Polar terms. Finally, we examined noisy responses in simple localization tasks. Variances of responses were better explained by a model which drew responses from noisy Polar representations compared to Cartesian, except for localization by saccade, where the Cartesian model was better. This contrast demonstrates that Cartesian and Polar representations can be distinguished, and that different systems can rely on different representational formats. Discussing representations, Marr (1982) made the point that: "how information is represented can greatly affect how easy it is to do different things with it." Our results suggest that the format of visual-spatial representation makes it easy to do things that are linear in Polar terms.

Acknowledgement: NSF bcs 1534568

22.23, 11:15 am **Efficient coding of natural images with Nonlinear-Linear-Nonlinear cascade model** Zhuo Wang[1,2](wangzhuo@nyu.edu), Xue-Xin Wei[3,4], Eero P Simoncelli[1,2,5]; [1]Howard Hughes Medical Institute, [2]Center for Neural Science, New York University, [3]Department of Statistics, Columbia University in the City of New York, [4]Center for Theoretical Neuroscience, Columbia University in the City of New York, [5]Courant Institute of Mathematical Sciences, New York University

Efficient coding theory is a normative principle that has been used to explain the structure of biological sensory systems. Particular instantiations of the theory have been shown to be consistent with various aspects of early visual processing, including receptive field (RF) selectivity and rectifying nonlinearities. Here, we examine coding efficiency of natural images in a cascaded nonlinear-linear-nonlinear model. Luminance values of each pixel first pass through an instantaneous nonlinearity with additive input noise, and this transduced signal is then spatially integrated by a population of linear-nonlinear neurons with additive output noise. We examine a discrete set of noise levels and transduction nonlinearities. For each combination, the linear RFs and parametrized nonlinearities of the entire population are optimized, to maximize the mutual information between the pixels of a set of natural images and the model responses, under a metabolic cost constraint. Building on previous work (Karklin & Simoncelli, 2011), we find that the choice of noise levels and transduction nonlinearity have profound effects on the qualitative properties of the optimal population. With small output noise, all optimal filters are oriented band-pass RFs, comparable to V1 simple cells, and similar to those found using Independent Component Analysis (Bell & Sejnowski, 1997) or Sparse Coding (Olshausen & Field, 1996). But with increasing output noise, a growing proportion of neurons adopt non-oriented low-pass RFs subdivided into ON/OFF subpopulations, similar to retinal ganglion cells. This transition is striking and highly reliable under a saturating gain-control transduction nonlinearity (e.g. a Naka-Rushton function), but is partial and incomplete under linear or logarithmic transduction nonlinearities. It remains to be seen whether photoreceptor transduction nonlinearities and noise levels, along with ganglion cell noise levels, are within the regime that theoretically predicts the emergence of ON/OFF RFs. In addition, we are currently exploring the generalization of this framework to spatio-temporal visual inputs.

Acknowledgement: Howard Hughes Medical Institute

22.24, 11:30 am **A spatial model of human retinal cell densities and solution for retinal ganglion cell displacement** Michael A Barnett[1](micalan@sas.upenn.edu), Geoffrey K Aguirre[2]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Neurology, University of Pennsylvania

Retinal ganglion cells (RGCs) are radially displaced from their receptive fields within ~20°r (retinal degrees) of the fovea, with the magnitude varying both by eccentricity and polar angle. Correction for this displacement is needed to relate measurements of the RGCs to measurements of the cones, perception, or cortex. Theoretically, displacement magnitude may be derived by relating the number of midget RGCs in a retinal patch to the number of midget receptive fields (RFs) at a corresponding visual field location (Drasdo et al., 2007). We have developed a spatial model of retinal cell populations that solves for RGC displacement at any arbitrary retinal position. We begin with empirical measurements of cone and RGC densities (Curcio et al., 1990). These values are transformed to midget RF and RGC density through parameterized, eccentricity-independent linking functions. We then use a constrained, non-linear search over the linking parameters to enforce convergence of the midget RF and RGC cumulative functions beyond 20°r. The difference in spatial position of equivalent values of the cumulative functions yields the degree of RGC displacement. The modeling code is available (https://github.com/gkaguirrelab/rgcDisplacementMap). The output of our model resembles empirical measurements of RGC displacement (Drasdo et al., 2007). We find a peak RGC displacement of 3.45°r, compared to an empirical value of 3.2. The calculated end of the displacement zone varies from 16°r in the nasal retina to 22°r on the temporal retina, consistent with empirical findings. The linking function parameters imply a midget RGC fraction as a function of eccentricity that is intermediate to prior models (Dacey 1993; Drasdo, 2007) and matches recent empirical measurements (Liu et al., 2017). Finally, we demonstrate that the model may be applied to individual subject data, making possible studies that link non-invasive measurements of cone and RGC density to visual function and cortical organization.

Acknowledgement: U01 EY025864

22.25, 11:45 am **Two-photon imaging evidence for spatial frequency and orientation tuning in macaque V1** Shuchen Guan[1](smileyguansc@163.com), Niansheng Ju[1], Shiming Tang[1], Cong Yu[1]; [1]Psychology, McGovern Brain Research, and Life Sciences, Peking University

One fundamental assumption in vision science is that outside stimuli are first parsed by linear spatial filters, or V1 neurons, tuned to a full range of orientations and spatial frequencies. However, single-unit evidence supporting this view is limited by relatively small sample sizes and potential sampling biases. Here we used two-photon calcium (GCaMP5) imaging to record orientation and SF tuning in thousands of V1 layers 2&3 (150 and 300-μm depths) neurons in two awake, fixating monkeys (two & one 850x850_μm2 windows, respectively, at ~3°parafovea). The stimulus was a high-contrast (0.9) drifting (2-cycles/sec) Gabor with 3 sizes (>=1-octave), 12 orientations, and 6 SFs (0.25-8 cpd). SF tuning: Most neurons are tuned to medium and high SFs (>=1-cpd), and very few to lower ones, with a tuning range of ~2 octaves. Tuning functions are mostly asymmetric, showing a shallower branch at lower frequencies, resulting a lower/higher half-bandwidth ratio at 1.58 and 1.46 in layer 2, and 1.67 and 1.21 at layer 3, respectively, in two monkeys. SF tuning also shifts to lower frequencies from layer 3 to layer 2, from 2.3 to 1.9 cpd and 5.2 to 4.0 cpd, respectively. Orientation tuning: Layer 2 neurons have a more isotropic distribution of peak orientation tuning than Layer 3 neurons. There is no evidence for a cardinal-over-oblique orientation tuning preference in terms of neuron numbers and tuning bandwidths. The near absence of low-SF V1 neurons suggests the necessity of revising the traditional linear-nonlinear model. Low-SF information may be responded by medium-SF neurons with their shallower tuning function branches toward low SFs, and later decoded by V2 neurons with SF tuning 2-octaves lower (Foster et al., 1985). The lack of evidence for an oblique orientation anisotropy is consistent with psychophysical data that the neural locus for the oblique effect is more central (Westheimer, 2003).

22.26, 12:00 pm **Cortical feedback mediates figure-ground modulation in the human lateral geniculate nucleus** Sonia Poltoratski[1,2,3](sonia09@stanford.edu), Alexander Maier[2,3], Allen Newton[4,5], Frank Tong[2,3,4]; [1]Department of Psychology, Stanford University, [2]Department of Psychology, Vanderbilt University, [3]Vanderbilt Vision Research Center, [4]Vanderbilt University Institute of Imaging Science, [5]Department of Radiology & Radiological Sciences, Vanderbilt University

The lateral geniculate nucleus (LGN) is the earliest site of the visual hierarchy that receives top-down feedback, yet the functional role of this feedback is poorly understood. However, growing research suggests that the human LGN is involved in more sophisticated visual and cognitive processes, showing modulation by covert attention (O'Connor et al., 2002) and evidence of orientation-selective processing (Ling et al. 2015). Here, we show that perceptual figures elicit an automatic form of feedback modulation that propagates from the binocular visual cortex to the LGN. This stimulus-driven feedback leads to the enhancement of figures in the LGN even in the absence of directed attention. Using high-resolution fMRI at 7 Tesla to record human brain activity, we first measured fMRI responses to orientation-defined figures presented to the left and right of fixation, cuing participants to spatially attend to one figure while ignoring the other. Spatial attention led to enhanced responses in the LGN, consistent with prior work, but more importantly, orientation-defined figures produced elevated responses even when the figure was unattended. In a second experiment, we manipulated whether the figure and the surround stimuli were presented to the same eye or to different eyes. This design leverages the binocular organization of the early visual system: V1 is considered the first stage along the visual hierarchy in which signals from the two eyes are strongly integrated. Nevertheless, we found that the LGN was reliably modulated when figure and ground were presented to different eyes, implicating a mechanism top-down feedback from binocular cortical neurons for figure-ground modulation in the LGN.

Acknowledgement: NIH T32EY007135, NIH P30-EY008126, NSF Grant BSC-1228526

22.27, 12:15 pm **Despite a 100-fold drop in cortical magnification, a fixed-size letter is recognized equally well at eccentricities of 0 to 20 deg. How can this be?** Denis G Pelli[1,2](denis.pelli@nyu.edu); [1]Psychology Dept, New York University, [2]Center for Neural Science, New York University

Formerly, peripheral vision has been modeled as central vision scaled by the cortical magnification (Virsu & Rovamo, 1979). That model is rejected by finding conservation across eccentricity of recognition of a fixed-size target. We find that efficiency and equivalent noise are conserved across 0 to 20 deg eccentricity. (Based on measured threshold contrast for identification of brief Sloan letter, with and without noise, using method of Pelli & Farell, 1999.) Thus, human ability to recognize a simple target is surprisingly immune to cortical magnification, and the neurons per deg2. Of course, if more targets are introduced, they crowd each other, unless separated by at least the crowding distance, which is inversely proportional to the cortical magnification (Pelli, 2008). The literature on crowding suggests that the area within the crowding distance in all directions feeds a recognition unit that can recognize a simple object (but not two) independent of its position in the unit's area. The conservation of recognition reported here implies that the larger (peripheral) recognition units recognize a fixed-size target just as well as the smaller (central) units, despite a 10,000-fold change in area from 0 to 20 deg. Instead of the Virsu & Rovamo scaling model, here we find that the recognition units implied by crowding vary in size but all recognize a fixed-size target equally well.

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Saturday Morning Posters

Development: Experience and disorders

Saturday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

23.301 **Preserved cortical organization in the absence of early visual input** Michael Arcaro[1](Michael_Arcaro@hms.harvard.edu), Peter F Schade[1], Margaret S Livingstone[1]; [1]Department of Neurobiology, Harvard Medical School

Recent studies on blind humans suggest that retinotopy persists even in the absence of retinal input. Hubel and Wiesel found that monocular deprivation resulted in profound changes in V1 architecture, but binocular deprivation did not. After binocular deprivation, early visual cortical areas seemed normal, but the animals were behaviorally blind. We therefore asked whether binocular deprivation altered the large-scale organization of higher visual areas. We tracked the functional development of visual cortex in two monkeys that were raised for the first year of life only experiencing diffuse-light through binocular suturing. We scanned these monkeys using fMRI in a variety of visual tasks and under rest conditions starting as early as 8 days and throughout the deprivation period. During deprivation, spontaneous activity patterns throughout visual cortex reflected the retinotopic organization typically found in normally-reared monkeys. Visual stimulation resulted in decreased activity relative to baseline. However, increased activity was found to coarse bar motion specifically within areas MT, V6, and LIP. Behaviorally, these monkeys learned to navigate in their cages such that it was difficult to differentiate them from the rest of the colony. After a year, eyelids were re-opened and they received visual form stimulation. Strikingly, both monkeys are behaviorally insensitive to visual stimulation. However, visual stimulation evokes strong positive responses throughout the visual system. Spatial frequency mapping revealed an eccentricity organization similar to normally-reared monkeys. Visual stimulation resulted in strong responses in inferotemporal cortex, but no differential between face, object, and hand categories. Our results demonstrate that visual cortex is retinotopically organized even in monkeys raised with no visual form experience. Despite this substantial organization, the monkeys were behaviorally blind, suggesting that the primate brain is immature at birth, and the organization that supports visual perception is heavily dependent on early experience.

Acknowledgement: NEI

23.302 **Assessing the functional properties of primary visual cortex in the absence of extrastriate visual areas.** Andre D Gouws[1](andre@ynic.york.ac.uk), Holly D Brown[1], Rachel L Woodall[1], Antony B Morland[1]; [1]Department of Psychology, University of York

Patient H was introduced to us several years after a stroke that resulted in an extensive unilateral lesion affecting her left occipital cortex and underlying white matter. She has a corresponding homonymous right visual field defect. Intriguingly, close inspection of MRI data of the occipital lobe suggested that cortical tissue is preserved within the calcarine sulcus in the damaged hemisphere, usually the location of V1. Little or no spared tissue is seen in locations that would usually represent visual areas V2, V3 and likely other extrastriate visual areas. As there is little evidence of atrophy of the cortex along in the calcarine sulcus, we sought to characterise the structural integrity of the projection from the LGN to it to establish whether there was a potential input to V1 that escaped the lesion. Tractography of diffusion-weighted imaging at 3T revealed an intact projection from the LGN to the spared calcarine tissue, and tract characteristics were comparable with those in H's healthy, right hemisphere. Next, we tested whether any residual activity to visual stimulation might be detected in spite of the dense visual field defect. A block-design, alternating left-vs-right visual field, fMRI experiment revealed robust BOLD responses in the spared calcarine tissue in both hemishperes to stimuli presented in the contralateral hemifield. Furthermore, standard fMRI retinotopic mapping paradigms revealed that functional responses remain organised in a manner consistent with an intact retinotopic map. Our results indicate that even after a considerable period of time since the lesion, an 'isolated' V1 registers its thalamic inputs, which remain organized retinotopically. It is interesting to note that the activity in V1 alone does not appear to underpin behavioural responses to stimuli.

23.303 **Posterior Cortical Atrophy: A longitudinal neurocognitive case study.** Josee Rivest[1,2](jrivest@yorku.ca), David Tang-Wai[3]; [1]Psychology, Glendon College, York University, Toronto, Ontario, Canada, [2]Centre for Vision Research, York University, Toronto, Ontario, Canada, [3]Neurology & Geriatric Medecine, University of Toronto, Toronto, Ontario, Canada

Posterior Cortical Atrophy (PCA) is a neurodegenerative disease that first develops in the occipital-parietal-temporal cortex. While its major pathological cause is the same as that of Alzheimer's disease (e.g. Tang-Wai & colleagues), the development of the cognitive changes over its course is quite different. Here we present a 6-year longitudinal account of the neurocognitive profile of a highly intelligent man (BG), starting from the year of his diagnosis to that of his death. Despite his normal visual acuity and visual fields, BG initially reported reading difficulties. Early in his disease, he had deficits in visual attention, processing speed and recognition. His recognition difficulties first presented as alexia without agraphia, followed by topographical disorientation, prosopagnosia, simultagnosia, and object agnosia. Next, his visuo-constructional, arithmetic skills, and visual memory gradually declined. Relative to his severe visuo-perceptual and recognition difficulties, his abilities to reach for objects remained functional. Serial MRI brains demonstrated progressive left-more-than-right occipital, temporal and parietal atrophy with relative sparing of the hippocampi. Four years following diagnosis, BG could no longer perform any visual tasks and started to develop significant expressive language difficulties. Over the full course of the disease, his motor abilities, verbal recognition and verbal logical memory remained functional, and his practical reasoning normal. BG's case illustrates that the neurodegenerative process involve in PCA can first affect the visuo-cognitive functions typical of the ventral system, extend to all functions dependent on the posterior areas, and eventually to language areas, all while sparing areas responsible for practical and logical verbal reasoning.

23.304 **Visual response properties of neurons in V1, V2 and V4 of an amblyopic macaque.** Brittany N Bushnell[1](bnb233@nyu.edu), Najib J Majaj[1], J Anthony Movshon[1], Lynne Kiorpes[1]; [1]Center for Neural Science, New York University

Most studies of neuronal responses in amblyopia have focused on primary visual cortex (V1) in anesthetized animals. Typically these experiments reveal decreased binocularity, and reduced contrast sensitivity and visual resolution in cells driven by the amblyopic eye (AE) compared to the fellow eye (FE). These neuronal deficits are less marked than behaviorally measured visual losses, implying that there are deficits in visual processing downstream of V1. Amblyopes are also impaired on complex tasks such as form discrimination that are thought to rely on extrastriate visual areas. We have therefore studied correlates of visual sensitivity and form discrimination in recordings from an awake, fixating macaque made amblyopic by early surgical esotropia. We recorded multiunit activity from two 96-channel Utah arrays, one along the V1/V2 border and one in V4. We briefly flashed a variety of stimuli onto the multiunit receptive fields, including sinusoidal gratings and radially modulated shapes. FE sites were generally more responsive than AE sites in V1, V2, and V4. Activity at many sites was binocular, but dominated by the FE. Monocular sites were usually driven by the FE. In V4, which in normal monkeys is wholly binocular, almost half of recording sites were monocular. In V1 and V2, high spatial frequencies evoked stronger responses in the FE than in the AE, but radial forms drove inconsistent activity. In contrast, most V4 sites were not tuned for spatial frequency, but many responded vigorously to radial forms. Most of these form-responsive sites responded exclusively or more strongly to the FE. This strongly FE-biased representation of form responses in V4 is consistent with the idea that changes in that area are related to the substantial deficits in form perception shown by many amblyopes (including the monkey subject of these experiments).

23.305 **Regional specialization of visual cortex in congenital blindness reveals takeover by multiple distinct top-down fronto-parietal inputs** Shipra Kanjlia[1](skanjli1@jhu.edu), Marina Bedny[1]; [1]Psychological & Brain Sciences, Johns Hopkins University

Recent evidence suggests that, in blindness, visual cortices become responsive to higher-cognitive information, including language and number. We hypothesize that this plasticity is mediated by takeover of visual cortex by multiple fronto-parietal networks that typically provide top-down feedback to vision. To test this hypothesis, we asked whether a) visual cortices participate in executive functions, which are also supported by fronto-parietal networks and b) whether executive functioning, numerical reasoning and linguistic processing colonize distinct "visual" regions. Congenitally blind and sighted control participants took part in three fMRI experiments. In a sentence comprehension experiment, participants either listened to spoken sentences or lists of non-words. In a math calculation experiment, participants solved math equations or processed sentences. Finally, we measured executive conflict using an auditory STROOP task. Participants judged whether the voice of a speaker was male or female. On congruent (C) trials, a female speaker said "female" or a male speaker said "male" and vice versa on incongruent (I) trials. On neutral (N) trials male and female speakers said gender-neutral words. In congenitally blind but not sighted individuals, parts of primary visual cortex (V1) were more active during incongruent than congruent trials ($F(1,18)=4.63$, $p< 0.05$; group interaction: $F(1,26)=5.45$, $p=0.03$). Different occipital regions, within and outside of V1, responded to language (sentence>nonwords; lateral and ventral occipito-temporal cortices (LO & VOT)) and numerical information (math>language; middle occipital gyrus (MOG)). Math- and language-responsive visual regions don't show a congruency effect (MOG: I&C>N $F(1,18)=0.01$, $p=0.94$, I>C $F(1,18)=1.96$, $p=0.18$; LO: I&C>N $F(1,18)=0.28$, $p=0.60$, I>C $F(1,18)=0.27$, $p=0.61$; VOT: I&C>N $F(1,18)=1.46$, $p=0.24$, I>C $F(1,18)=0.02$, $p=0.88$). We conclude that, in congenital blindness, "visual" cortex becomes sub-specialized for multiple distinct higher cognitive functions, including domain general executive conflict, language and numerical processing. We hypothesize that this plasticity is related to the intrinsic long-range top-down connectivity to the visual system from fronto-parietal networks.

23.307 **Behavioral and Neural Changes in Early Visual Processing 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, [2]Behavioral and Neural Sciences Graduate Program, Rutgers University, Newark, NJ

Schizophrenia (Sz) affects about 1% of the population. Alterations of visual perception are frequently reported in schizophrenia. They offer information on disease progression and severity beyond what can be gathered through traditional neuropsychological tests alone. In line with established theories of Sz, we hypothesize that NMDA-receptor hypofunction might underlie changes in visual processing. To test this hypothesis, we are developing a nonhuman primate model to quantify both visual perception and its underlying neural mechanisms. To test the NMDA hypofunction hypothesis, we injected rhesus monkeys (M. mulatta) either with an intramuscular injection of a sub anesthetic dose of the NMDA-receptor antagonist ketamine (0.3 mg/kg), or with saline (control). We performed behavioral experiments to quantify visual perception and multi-electrode array recordings in V1 to document neural response changes. In the behavioral experiments, we quantified the strength of a contrast-contrast illusion: in healthy human subjects, the perceived contrast of a grating is reduced by its surround, patients with Sz are less susceptible to this so-called Chubb illusion. In each trial, we presented two gratings with variable contrasts and with or without surrounds. The monkey's behavior reflected a clear Chubb illusion. Consistent with the NMDA hypofunction hypothesis, the strength of the illusion was reduced after the injection of ketamine. In the electrophysiology experiments, we investigated neuronal gain, which is thought to be reduced in Sz. We presented whole-field visual flicker to quantify the steady state visual response gain and found that ketamine injections led to an overall reduction in the gain. Our current efforts are focused on corroborating these findings in additional animals and on performing simultaneous behavioral and electrophysiological recordings to establish a direct link between neural and behavioral responses.

Acknowledgement: R01 EY17605

23.308 **Relationship Between Iterative Visual Processing Deficits and Psychotic Symptoms** Tori Espensen-Sturges[1](espe0107@umn.edu), Philip C Burton[3], Scott R Sponheim[1,2,4], Cheryl A Olman[2]; [1]Department of Psychiatry, University of Minnesota, [2]Department of Psychology, University of Minnesota, [3]Center for Magnetic Resonance Research, University of Minnesota, [4]Veteran's Affairs Medical Center, Minneapolis, MN

Feedforward and feedback signals between specialized visual areas create iterative processing loops that combine information across receptive fields and increase processing efficiency. A variety of visual processing deficits have been observed in psychosis that seem to exist separately from generalized deficits and may be explained by abnormal iterative processing. In an effort to isolate and better understand the components of these loops in visual deficits in psychosis, we presented schizophrenia patients, bipolar patients, and controls with arrays of short line segments describing an object set on a background of parallel line segments as part of an MRI experiment. Stimuli were defined as being either meaningful objects or meaningless clusters of line segments based on a separate categorization experiment. BOLD responses in primary visual cortex (V1) and lateral occipital complex (LOC) were estimated using a general linear model, and connectivity measures were determined using a generalized psychophysiological interaction analysis. There were no group differences in any visual ROI; however, there were negative correlations between LOC activation and self-reported difficulty modulating stimulus intensity, as well as absorption, a personality trait associated with psychosis. A generalized PPI analysis using V1 as a seed region revealed differential relationships with the right LOC and a medial frontal cluster (BA 9) depending on stimulus condition. The relationship between V1 and rLOC was positive for meaningless stimuli and negative for meaningful stimuli; this pattern was reversed for the relationship between V1 and BA9. The magnitude of the difference in correlation strength between meaningful and meaningless objects was associated with more severe negative psychotic symptoms, strengthening the suggestion that processing in psychosis may be better understood in terms of psychotic symptomatology than diagnosis. In addition, relationships involving multiple stages in the visual processing stream with symptomatology highlight the importance of deficits in iterative processing in psychotic disorders.

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23.309 **Psychophysical and fMRI Assessment of Magnocellular and Parvocellular Responses in Patients with Parkinson's Disease** Claudia Feitosa-Santana[1,2,3,4](claudia@feitosa-santana.com), Liana Guerra Sanches[1], Daniel Quintela Bertuzzi[2], Edson Amaro Junior[1], Dora Fix Ventura[3,4]; [1]Hospital Israelita Albert Einstein, [2]Universidade Federal do ABC, [3]Núcleo de Neurociências e Comportamento, Universidade de São Paulo, [4]Departamento de Psicologia Experimental, Instituto de Psicologia, Universidade de São Paulo

Motor effects of Parkinson's disease (PD) are well known but visual aspects are seldom studied. Although questionable (Gaines, 2006), psychophysical measures of magnocellular (M) and parvocellular (P) visual pathways have shown losses in PD patients (Silva et al., 2005). The objective of this study was: (1) the psychophysical evaluation of luminance contrast discrimination in patients with PD (n=28; mean= 50 ± 9 years old) and age-matched controls using stimuli designed to be selective for M and P pathways in two computerized tests: Pedestal Test (Pokorny & Smith, 1997; Gualtieri et al., 2006) and Checkerboard Test (Benoff et al., 2001; Costa, 2011); (2) the comparison of PD subgroups: early-onset PD (EOPD) (onset before 50 years old; n= 19, mean= 46 ± 6 years old), and late-onset PD (LOPD) (onset after 50 years old; n= 9; mean= 58 ± 6 years old); and (3) the fMRI assessment with an adapted version of the Checkerboard Test for PD patients (n= 14; mean= 52 ± 10 years old) and age-matched controls. The results indicated: (1) the Pedestal and Checkerboard Tests shows that losses occur in both M- and P-pathways in PD-patients; (2) the comparison of the performance of the PD-subgroups with the controls suggests that the M- and P-pathways were impaired in both LOPD- patients (Pedestal

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Test) and EOPD-patients (Checkerboard Test). In addition, this is the first study to suggest that impairments of the M- and P-pathways in LOPD-patients are greater than in EOPD-patients (inferred by Pedestal Test); and (3) fMRI responses showed no differences for M- and P-pathways selective stimuli across groups. ROI analysis for V5 and V4 also showed no difference for either P- or M-pathway. These results indicate possible dissociation between the fMRI measures and the psychophysical measures. Future studies with larger samples and/or samples from other populations are necessary.

23.310 **Atypical Basic Psychophysics in autism: Violation of Weber's law in vision and haptic** Batsheva Hadad[1](bhadad22@gmail.com), Sivan Schwartz[1], Orit Nizri[1], Nof Harel[1]; [1]University of Haifa

Perceptual atypicalities are widely acknowledged but poorly understood features of autism. The underlying assumption in prevailing models is that atypicalities result from reduced top-down influences, but sensory processing is intact. Changes in bottom-up factors, if they exist at all, are considered quantitative, mostly involving changes in noise levels. Consequently, testing has been limited to mid- and high-level processes, with little consideration of potential underlying constraints of basic sensory-perceptual processing. We show here that the widely-documented modulated context effects in autism reach deeper than hitherto suspected, with reduced inferential perception in stimulus encoding, during which the system constructs and continuously updates a generative model of the sensory inputs it receives. Specifically, we tested the adherence of vision and haptic to Weber's law, a fundamental principle of transient plasticity, whereby the output of processes depends not only on the absolute change but also on its calibration based on the immediate standard stimulation. According to Weber, sensitivity along intensities changes based on a rule of DI/I=C, where DI is the increase in intensity to a stimulusI that is required to produce detectable changes. Weber fractions (C) should thus remain constant. We measured JNDs for size visual judgments (Exp. 1), and for weight haptic discrimination (Exp. 2), based on the best-fitting individual psychometric functions. Results for the TD group confirmed Weber's law, demonstrating a linear increase in JNDs with intensity, resulting in constant fractions (DI/I) across intensities. The results for ASDs, in contrast, showed no scaling of JNDs with intensities; instead, fractions decreased linearly with intensities. In a striking contrast to its consistency in typical perception, Weber's law does not hold in visual and haptic perception in autism. This general, low-level altered mechanism may account for atypical perception demonstrated in higher-level processing and for sensory symptoms in autism.

Acknowledgement: Israel Science Foundation (ISF)

23.311 **An eye for detail: Is spatial frequency processing a source for enhanced cortical functioning in people with autism spectrum disorder?** Todd P Kamensek[1,3](todd.kamensek@alumni.ubc.ca), Fakhri Shafai[1,3], Grace Iarocci[2], Ipek Oruc[3]; [1]Graduate program in Neuroscience, University of British Columbia, [2]Department of Psychology, Simon Fraser University, [3]Department of Ophthalmology and Visual Sciences, University of British Columbia

Autism Spectrum Disorder (ASD) is a developmental disorder characterized by deficits in social-communication and interaction in addition to restricted and repetitive behaviour and interests (APA, 2013). Despite these deficits, a few studies have shown superior performance in various visual tasks, such as visual search (O'Riordan et at. 2001) and embedded figures (Shah and Frith 1983). It has been suggested that these atypicalities can be attributed to enhanced functioning of low-level perceptual processes (Mottron et al, 2006). In the present study we examined basic visual processing of spatial frequency (SF) as a potential source for enhanced perceptual functioning (EPF). We employed three experiments to asses three distinct aspects of SF perception: sensitivity, precision, and accuracy. In Experiment 1, using a 2-interval forced choice (2-IFC) detection paradigm, contrast sensitivity was measured at eight SFs (1-24 cpd). In Experiment 2, we assessed precision as a function of spatial frequency via a 2-IFC discrimination paradigm. In Experiment 3, accuracy of SF perception (i.e., veridical perception) was assessed via a method-of-adjustment paradigm. Finally, in Experiment 4 we implemented a search experiment that has reliably demonstrated superior performance in people with ASD in previous studies (Hessels et al. 2014; Kemner et al. 2008; O'Riordan et al. 2001) to explore possible associations between performance in our first three experiments, and performance in visual search. No evidence for enhanced perceptual functioning was found in any of our three experiments examining sensitivity, precision, or accuracy of SF perception in ASD (N=10) compared to age-, gender-, IQ-matched controls (N=16). In addition, results from the search experiment failed to replicate previous findings of superior performance in ASD. These findings are consistent with our previous research on visual orientation perception (Shafai et al. 2015) and suggest that enhanced low-level visual processing is not a source of EPF in autism spectrum disorder.

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23.312 **Direct Neural Read-Out of Binocular Rivalry Dynamics in Autism using EEG** Alina Spiegel[1,2](aspiege4@jhmi.edu), Jackson Lee[1,3], AJ Haskins[1], Nancy Kanwisher[1], Caroline E Robertson[1,4]; [1]McGovern Institute for Brain Research, MIT, [2]School of Medicine, Johns Hopkins University, [3]Duke University, [4]Harvard Society of Fellows, Harvard University

Intro: We have previously shown atypical binocular rivalry dynamics in individuals with autism, which are predictive of clinical measures of autistic symptomatology (Robertson et al., 2013) and likely reflect reduced GABAergic action in the autistic visual cortex (Robertson et al., 2016). As a simple visual assessment, rivalry could serve as an objective marker of autism. But traditional binocular rivalry paradigms have a key limitation: rivalry is a self-report measure, restricting its use to high-functioning, verbal individuals. Here, we aimed to develop a neural marker of binocular rivalry dynamics – and rivalry differences in autism – using electroencephalography (EEG). Methods: 46 participants (23 autism and 23 age- and IQ-matched controls) viewed true and simulated binocular rivalry displays (18, 30-second trials each) through a mirror stereoscope while EEG signals were recorded over occipital cortex. Signals corresponding to each eye's stimulus were independently measured. Behavioral report was collected using button-press. Results: First, we replicate our previous behavioral findings, including slower switch-rates and reduced perceptual suppression during binocular rivalry in individuals with autism (both $p< 0.006$). Second, these effects were directly mirrored in individuals' neural activity, as recorded from Oz: individuals with autism exhibited slower rivalry rates than controls ($p=0.01$). Third, using machine-learning analyses, we were able to correctly classify individuals' perceptual state (left eye, right eye, mixed) as well as diagnostic status (autistic vs. controls) with accuracies greater than 70%. Conclusions: Our results demonstrate a direct neural read-out of altered binocular rivalry dynamics in individuals with autism, predictive of diagnostic status, and provide a non-verbal method for quantifying binocular rivalry switch-rates. Down the road, this paradigm may offer an inexpensive, objective, neural marker of autism that can be used with non- and pre-verbal individuals as well as in animal models of the condition.

23.314 **The Effects of Glaucoma on Quality of Life in Canadian Seniors** Lauren A King[1](lak236@mun.ca), Ken Fowler[1], James R Drover[1]; [1]Department of Psychology, Memorial University of Newfoundland

Glaucoma is the third leading cause of blindness worldwide. In Canada, approximately 7.9% of seniors have glaucoma. Although researchers have investigated the effects of glaucoma on quality of life (QoL), none have investigated its impact on multiple aspects of QoL in a single sample. In the present study, we investigate the effects of glaucoma on four dimensions of QoL, namely, physical well-being, social well-being, emotional-well-being, and development and activity. Participants included 16,369 seniors who completed the Healthy Aging Survey from the population-based Canadian Community Health Survey (CCHS). Of this sample, 1,299 reported having glaucoma. Responses to 21 survey questions, each representing a single dimension of QoL, were analyzed. Collectively, these questions represented four dimensions of QoL. Responses to scaled questions from participants with glaucoma were compared to responses from the senior population using single sample t-tests. Responses to binary (yes/no) questions were analyzed using Chi square. Analyses indicated that compared to the population, participants with glaucoma scored poorer on questions representing social and emotional well-being as they reported more loneliness and less life satisfaction (all $p< .05$). Glaucoma

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affected numerous aspects of physical well-being as participants reported lower self-perceived health, less engagement in light sports recreation, and fewer hours per day of exercise and walking (all p< .05). Glaucoma also affected development and activity as compared those without glaucoma, a higher proportion of participants with glaucoma required assistance with personal care, house activities, transportation, and meal preparation or delivery (all p< .05). Also, participants with glaucoma drove less frequently (p< .05). Glaucoma affected four dimensions of QoL, yet most of the effects were reported for physical well-being, and development and activity. Specifically, participants with glaucoma felt less healthy and were less active than the senior population. They were also more likely to require assistance with aspects of daily life.

23.315 **Persistent Visual Impairment in Multiple Sclerosis: Prevalence and functional consequences.** Rachel A McKay[1](rachel.mckay3@gcu.ac.uk), Marianne EF Piano[2], Peter J Bex[3], Jennifer A Preston[1], Ben W Stansfield[1], Anita J Simmers[1]; [1]School of Health and Life Sciences, Scotland. , [2]School of Health Sciences, University of Surrey, England., [3]College of Science, Northeastern University, Boston, US.

Impaired visual function is a concern for up to 80% of people who have received a diagnosis of multiple sclerosis (Balcer 2015), and may result from involvement of structures in the afferent visual pathways, ocular motor systems or from cerebral deficits. Although visual symptoms in pwMS may precede, occur simultaneously with, or follow the development of other neurologic manifestations, they may represent the most prominent symptoms from the person living with MS's point of view. In a mixed methods study 110 participants completed a series of quality of life questionnaires (VFQ-25 with 10item neurological add-on, MSIS-29) and a full visual (HCVA, Contrast Sensitivity Function – spatial and temporal, ocular alignment and motility, colour vision, confrontational visual fields, stereoacuity and Pulfrich's) and functional assessment using the Multiple Sclerosis Functional Composite and the King-Devick Test. A small subgroup (n=10) undertook a further assessment of visual fields, motion coherence, OCT and balance using the Biosway Portable Balance Test. In Stage One pwMS reported greater persistent visual dysfunction impacting on daily life when compared with a non-MS, eye disease free population. Clinical assessment in Stage Two found that while visual deficits previously reported as cause for concern in pwMS – high contrast acuity, visual fields, colour and binocular vision did not appear to affect pwMS longitudinally, contrast sensitivity function was a significant cause of persistent visual loss impacting on daily life in pwMS. In Stage Three motion coherence was also found to be impaired causing difficulties with daily life. The study findings demonstrate a significant loss in visual perception in pwMS when testing in both the temporal and spatial domain. These persistent visual losses correlated with self-reported visual function and functional assessment having implications for guiding future rehabilitation strategies.

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Motion: Biological and flow

Saturday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

23.316 **Serial dependence effect in heading perception from optic flow** Qi Sun[1](979493161@qq.com), David Alais[2], Huihui Zhang[2], Li Li[1,3]; [1]Department of Psychology, The University of Hong Kong, Pokfulam, Hong Kong SAR, [2]School of Psychology, University of Sydney, Sydney, Australia, [3]NYU-ECNU Institute of Brain and Cognitive Science, New York University Shanghai, Shanghai, PRC

Perception of current stimuli can be affected by recently seen stimuli, known as serial dependence. In studies of self-motion (heading) perception, previous work shows perceived direction is biased towards the center of the display. Here we examined serial dependence in heading perception after removing center bias. In Experiment 1, the display (80º x 80º) simulated observer translation (3 m/s) in a 3D random-dot cloud (depth range: 0.565-2.0 m) consisting of 200 dots. On each trial, heading direction was randomly chosen (±32°, ±16°, ±8°, ±4°, ±2° or 0°) and presented for 0.5 s. Participants indicated perceived heading with a mouse-controlled probe. Experiment 2 varied signal-to-noise ratio by replacing 0%, 25%, 50%, or 75% dots with random-motion vectors. Experiment 3 increased dot number to 500 to increase motion signal strength. To evaluate center bias, we performed a linear regression between perceived and actual heading. To evaluate serial dependence, after subtracting the center-bias, we performed another linear regression between the heading bias (the residual difference between perceived and predicted heading on the current trial) and relative heading offset (difference between perceived heading of the previous trial and actual heading of current trial). We found: (1) a repulsive serial dependence in heading perception from optic flow; (2) increased center bias and serial dependence effects with decreasing signal-to-noise ratio; (3) both effects decreased with the increased number of motion signals in the flow field. Our study is the first to evaluate serial dependence in heading perception from optic flow and finds a negative (repulsive) effect. We show that signal strength in the flow field affects heading judgments, with lower signal strength increasing center bias as well as the reliance on judgments in previous trials.

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23.317 **Statistical characterization of heading stimuli in natural environments using SLAM** Christian B Sinnott[1](csinnott@nevada.unr.edu), Tung Dang[2], Christos Papachristos[2], Kostas Alexis[2], Paul MacNeilage[1]; [1]Department of Psychology, Cognitive and Brain Sciences, University of Nevada, Reno, [2]Department of Computer Science, University of Nevada, Reno

Heading is the direction of linear self-motion in head coordinates. It may be estimated based on vestibular signals that provide information about linear acceleration and based on visual optic flow signals that provide information about linear velocity. Prior psychophysical studies have documented significant repulsive biases in perception of both visual and vestibular heading (Cuturi & MacNeilage 2013), meaning that heading azimuth angle is perceived to be more eccentric than the presented stimulus. Theoretical work suggests that such biases may result from a combination of efficient encoding and probabilistic decoding, where both encoding and decoding mechanisms are constrained based on natural stimulus distributions (Wei & Stocker 2015). To our knowledge, these distributions for heading stimuli remain undocumented, so we set out to characterize them. Tracking linear head velocity in natural environments using a head-based system is challenging. Recording of linear head acceleration using an inertial measurement unit (IMU) results in velocity estimates subject to drift, while optic flow analysis of video from a head-mounted camera is subject to ambiguity due to superposition of linear and angular flow and unknown scene scale. To overcome these limitations we adopted visual-inertial odometry technology developed for autonomous robots that perform localization and mapping (SLAM). Subjects wore a head-mounted device with calibrated, integrated camera and IMU. The data fusion pipeline yielded robust estimates of linear and angular position (in world-frame coordinates) and velocity (in head-frame coordinates) as subjects moved freely. The distribution of heading azimuth and elevation was peaked near straight ahead, as expected based on natural walking with head facing forward. Standard deviation of heading azimuth and elevation was 19 deg and 14 deg respectively, in line with the observed range of angular compensatory head movements. These highly peaked distributions are qualitatively consistent with predictions of repulsive biases based on efficient encoding and probabilistic decoding.

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23.318 **The neural basis of actively controlled visually simulated self-motion** Constanze Schmitt[1](constanze.schmitt@physik.uni-marburg.de), Milosz Krala[1], Frank Bremmer[1]; [1]Dept. Neurophysics and Marburg Center for Mind, Brain and Behavior – MCMBB, 35043 Marburg, Germany

Navigating through an environment requires knowledge not only about one's direction of self-motion (heading), but also about traveled distance. Previous behavioral studies have shown that human observers are able to actively reproduce a previously observed travel distance purely based on visual information. Here, we employed EEG to determine the neural substrate of actively controlled simulated self-motion as well as of distance reproduction. We measured event-related potentials (ERPs) during visually simulated straight forward self-motion across a ground

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plane. The stimulus was presented on a computer monitor 68 cm in front of the human observers, subtending the central 37° * 11° degrees of the visual field. The participants' task was to reproduce (active condition) a previously seen self-displacement (passive condition). Subjects had full control over travel speed, using a gamepad. We recorded the trajectories of self-motion during the active condition and played it back to the subjects in another set of trials (replay condition). A motor control condition was included to control for purely action-related ERPs. EEG-data were aligned to the onset or to the offset of the simulated self-motion. Additionally, if participants' actively traveled distance was longer than the remembered (control) distance, we aligned behavioral and EEG data also to the time point ToCD (Time of Control Distance) when the control distance had been passed. Evoked ERPs revealed higher amplitudes in the passive as compared to the active condition. This result is in line with the idea of attenuated responses to self-induced vs. externally-induced sensory stimulation. Wavelet based temporal-frequency analyses revealed activation in the theta-band in the active condition about 600 ms – 300 ms before the end of the movement. Interestingly, this time window coincides with the ToCD. This theta-band activation could be indicative of a neural comparator for action-related predictions and sensory outcomes.

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23.319 **Heading Through A Crowd** Hugh Riddell[1](hugh.riddell@uni-muenster.de), Markus Lappe[1]; [1]University of Muenster

When an observer moves through the world a pattern of expanding motion known as optic flow is generated on the retina. Motion that is external to an observer perturbs the optic flow and can cause inaccuracies in heading estimation. Despite this, we are able to navigate through noisy environments, such as crowds. In crowds, external motion is produced by both the movement of other people though the scene, as well as their limb movements. One way that the visual system could simplify the computation of heading through crowds is by taking into account biological motion information, which provides cues as to the motion of the individuals within a crowd. To investigate this possibility, we measured heading accuracy during self-motion through crowds of point-light biological motion. We found that biological motion has a negative impact on heading estimation when people within a crowd move their limbs but do not move through space. When walkers moved independently through the scene, however, the presence of limb motion improved heading accuracy. This occurred for crowds containing both regular and perturbed walkers, suggesting that the observed effect does not stem from the processing of biological motion per se, but is likely produced by low-level cues inherent in the gait patterns of walkers.

23.320 **Cortical areas that integrate motion and form cues for the perception of self-motion** Shu-Guang Kuai[1,2](sgkuai@ecnu.edu.cn), Zhe-Xin Xu[1], Jing Chen[2], Jia-Mei Li[1], David T Field[3], Li Li[2]; [1]The School of Psychology and Cognitive Science, East China Normal University, China, [2]NYU-ECNU Inst. of Brain and Cognitive Science, New York University Shanghai, China, [3]Center for Integrative Neuroscience & Neurodynamics, Department of Psychology, University of Reading, UK

When moving around in the world, the human visual system uses both form and motion information to estimate the direction of self-motion (i.e., heading). Here we explored brain areas that integrate motion and form cues for heading perception. We used stimuli consisting of 200 randomly distributed dot pairs oriented toward a locus on a screen (the form-defined focus of expansion (FOE)) but moved away from a different locus (the motion-defined FOE) to simulate observer translation. In Experiment 1, we fixed the motion-defined FOE at the display center and shifted the form-defined FOE from -5° to 5° at the step of 2°. In Experiment 2, the form- and motion-defined FOEs were congruent (i.e., at the same location in the display) or incongruent (i.e., on the opposite side of the display) but had the same shifts. Participants made a task-irrelevant (luminance discrimination) judgment during scanning. We preformed the searchlight and ROI-based multiple voxel pattern analysis and found that early visual areas (V1, V2) decoded both form- and motion-defined FOEs but could not discriminate the congruent and incongruent conditions, suggesting that these areas do not integrate form and motion cues for heading perception. The higher ventral areas (V3v, V4v) decoded form- but not motion-defined FOE while the dorsal areas (MT+) and parietal lobe (VIP , CSV) decoded motion- but not form-defined FOE. In contrast, the higher dorsal areas (V3d, V3a, V7, KO) not only decoded both form- and motion-defined FOEs but also dissociated the congruent and incongruent conditions, suggesting that they contribute to the integration of form and motion cues for heading perception. Our findings provide the first empirical evidence suggesting that form and motion information are first processed along separate pathways and then integrated in the higher dorsal areas for the final estimation of heading during self-motion.

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23.321 **Vection modulated by awareness to the own body** Michiteru Kitazaki[1](mich@cs.tut.ac.jp), Satoshi Fujisawa[1], Hyuga Tanimoto[1], Maki Sugimoto[2], Masahiko Inami[3]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Department of Information and Computer Science, Keio University, [3]Research Center for Advanced Science and Technology, The University of Tokyo

Humans perceive illusory self-motion when a coherent motion is presented in a large visual field (vection). It is dominated by a larger motion field, motion of the background, and non-attended motion, and enhanced by a perspective jitter (Kitazaki & Sato, 2003; Palmisano, et al., 2015). However, an effect of awareness to observer's own body has not been investigated. Illusory body ownership to an avatar in a virtual environment is elicited by contingent visual movements of the avatar body with the observer's action (Gonzalez-Franco, et al., 2010). We aimed to test if the awareness to the body ownership modulates vection in a virtual environment. In Experiment 1, ten naive subjects wore a head-mounted-display and observed a virtual room rotating around them to induce circular vection for 30s following a body ownership period for 300s. In the body ownership period, they were asked to move their legs and feet to step on randomly appearing circles. The avatar body in the virtual environment was visible and moved synchronously with subjects' action (visible condition) or invisible (invisible condition). Subjects performed four repetitions of the combination of the visibility condition (visible and invisible) and the directions (left and right). We found that the latency of vection was shorter (p=.070) and its duration was longer (p=.038) for the visible condition than the invisible condition. In Experiment 2, we used the synchronous condition that was identical to the visible condition in Experiment 1, and the asynchronous condition that the avatar moved independently of subjects' action for the body ownership period (n=9). The latency of vection was shorter (p=.022) and its duration was longer (p=.021) for the synchronous condition than the asynchronous condition. To conclude, the awareness to the own body or the sensation of body ownership with the visible and synchronously moving avatar enhances perception of vection.

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23.322 **Curvilinear motion perception during visually simulated head turns in stereoscopic 3D virtual reality.** Aden C Garnett[1](captain-dragon@hotmail.com), John A Perrone[1]; [1]School of Psychology, The University of Waikato, New Zealand

Humans can determine their self-motion from retinal image motion. The process is not fool-proof however and many conditions create incorrect percepts of self-motion. One problem scenario is when visual rotation occurs around a person's centre of mass during translation. Historically, participants experiencing this have reported impressions of traveling around a curve. It is difficult to measure this however because it requires a simultaneous estimate of both heading and curvature. We have developed a new virtual reality based response tool that allows fast and intuitive reporting of perceived path, and from which perceived heading and rotation may also be inferred. This tool consists of a line projecting from the participant into a virtual world. The line is directed with hand movement and curved using controller input. Eighteen participants viewed 165, 2 second long forward translations (1.5ms-1) over a textured plane while experiencing visual rotation of between 0 and ±7.5deg/s. They used the new tool to indicate their perceived self-motion. Individuals reported consistently curved paths despite moving straight ahead. Greater variation in perceived path across trials was observed however at higher rates of rotation (mean SD curvature (±7.5deg/s) = .055m-1) than lower rates ((±0.6deg/s) = .006m-1). Absolute mean curvature at ±7.5deg/s rotation was .099m-1 (SE = 0.018m-1), consistent with the curvature of the circular path corresponding to 7.5deg/s rotation and 1.5ms-1 translation, although there were significant individual differences. There was also a strong (r = .70) relationship between ability to determine heading and ability to determine one's rate of rotation t(16) = 3.88, p < .001. Finally, there was anecdotal evidence that memory of path decays rapidly, with participants acknowledging resorting to guesswork if they delayed for as little as two seconds when responding. This supports the use of our tool which minimizes the time required to obtain heading and rotation estimates.

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23.323 **Heading Perception Depends on Time-Varying Evolution of Optic Flow** Charlie S Burlingham[1](charlie.burlingham@nyu.edu), David J Heeger[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Purpose: Is heading perception computed from instantaneous optic flow? Background: For observer translation, heading direction is indicated by a singularity in the optic flow field, the point in the image at which optic flow is zero. When an observer rotates while translating, the singularity is displaced and no longer corresponds to heading. Methods: Observers viewed moving patterns and made forced-choice heading judgements. Each moving pattern consisted of a collection of grating patches. Each patch was a plaid composed of two orthogonal gratings (sf = 3 cycles/°; overall contrast = 100%) multiplied by a raised cosine envelope (diameter = .25°). No patches were presented within a central rectangular region, ensuring that observers could not directly track the singularity of the flow field. There were three stimulus conditions: envelope motion, phase motion, and time-varying phase motion. For envelope motion, each patch (both the envelope and the plaid) was displaced on each frame. This stimulus contained two cues that could potentially compensate for rotation: the trajectories of the patches and time-varying optic flow. For phase motion and time-varying phase motion, the plaid envelopes remained stationary while the phases of the gratings shifted over time. The phase velocity of the plaid patches corresponded to either a single optic flow field (phase motion) or a sequence of flow fields (time-varying phase motion). Phase motion conveyed only instantaneous optic flow. Time-varying phase motion conveyed time-varying optic flow, but not patch trajectories. Results: Heading judgements were strongly biased for phase motion, indicating that observers misinterpreted rotation as additional translation. Observers were able to compensate for the rotation in the envelope motion and time-varying phase motion conditions, removing more than 50% of the bias. Conclusion: Instantaneous optic flow is insufficient for accurate heading perception. Time-varying optic flow is needed.

23.324 **The contribution of viewpoint oscillations to the perception of distance travelled from optic flow** Martin Bossard[1](bossard.martin@gmail.com), Daniel Mestre[1]; [1]Aix-Marseille Univ, CNRS, ISM, Marseille, France

When exploring their environment, humans and other animals have the ability to use many sources of information to estimate the distance they travel. Several studies have shown that optic flow is a significant cue to perceive distance travelled. Furthermore, it was found that adding various viewpoint oscillations to a purely translational optic flow, simulating forward self-motion, modulated this perception. In a series of experiments, we tested whether the perception of distance travelled was also affected by viewpoint oscillation, similar to head motion during natural walking. A first series of experiments, participants were exposed to an immersive optic flow simulating forward self-motion and they were asked to indicate when they thought they had reached the remembered position of a previously seen target. The main conclusion from these experiments is that viewpoint oscillations improve the perception of distance travelled. Moreover, this effect appears to be linked to an increase in global retinal motion. However, the "ecological" contribution cannot be ruled out. Manipulating different viewpoint oscillation frequencies showed that the optimal performance was observed for a range of frequencies close to that observed for the head motion during natural walking. Two further experiments aimed to test whether the idiosyncrasy of viewpoint oscillations affects the perception of distance travelled in stationary observers and whether the absence of their own viewpoint oscillation played an important role in subjects' estimates, while they were walking on a treadmill. And finally, in a last experiment we tried to develop a dynamic measure of distance travelled to a previously seen target, with a continuous pointing task method. Overall, our results show that viewpoint oscillations play an important role in visual self-motion perception and that several parameters (including visual information, proprioceptive information and ecological aspects of natural walking) seem to be involved in this process.

23.325 **Perception of Intentionality in Avatars and AI Agents** Serena De Stefani[1](serena.destefani@rutgers.edu), Sam Sohn[2], Mubbasir Kapadia[2], Jacob Feldman[1], Peter Pantelis[1]; [1]Psychology Department, Rutgers University, [2]Computer Science Department, Rutgers University

Many studies have demonstrated that motion can convey intentionality and mental goals, particularly when it is interpreted as originating from an animate agent (Tremoulet & Feldman, 2000). But an AI agent can also convey the intention to do something if it mimics human behavior in the right ways. In these studies, we sought to understand what aspects of behavior are particularly effective at distinguishing human from robot behavior, or in making them seem equivalent. We wondered in particular whether the efficiency with which a task is accomplished might influence judgments of humanness. We chose to study the traveling salesman task, which can be solved optimally by both computers and humans (at least for small numbers of locations) albeit with different computational strategies (MacGregor & Chu, 2000). In this task, the optimality of a solution can be quantified as the ratio between the total length of a solution and the the length of the optimal solution. We also studied other potential factors influencing such judgments, including the sequence in which the targets are visited, the duration of movements between successive targets, the direction of the agent's gaze, and the number of targets viewed while completing the task. In a series of experiments, we recorded an AI agent's behavior at different levels of optimality, and then asked human subjects to evaluate its intelligence, its planning capacity, and whether it was controlled by a human being or not. We also asked other human subjects to solve the same task using a virtual avatar, and asked other participants to evaluate their performances in a similar fashion. Results of initial studies show that both optimality and gaze behavior are correlated with the perceived humanness of the agent, suggesting that computational efficiency and gaze variance may serve as cues for distinguishing human from artificial intelligence.

23.326 **Individual differences in the use of form and motion in the perception of sex in biological motion displays.** Eric Hiris[1](ehiris@uwlax.edu), William McLoughlin[1], Gaokhia Yang[2], Sean Conway[3]; [1]Department of Psychology, University of Wisconsin – La Crosse, [2]Department of Psychiatry, Stony Brook Medicine, [3]Department of Psychology, University of Wisconsin – Oshkosh

Past research on individual differences in biological motion perception has used different tasks as a way of determining the relative use of form and motion information. However, a single task, the identification of the sex of a biological motion actor, can be based on form information, motion information, or both. We collected data from 76 observers completing a sex identification task to determine what information observers used to complete the task. In intermixed trials, participants viewed biological motion displays that varied in 1) both motion and form information, 2) just motion information, and 3) just form information. In addition to basic demographic information, participants also completed ADHD measures and surveys on autism, empathy, social anxiety, and the vividness of movement imagery. We analyzed the biological motion data by examining the slopes of logistic regression functions for the three types of biological motion displays. Observers were classified as using motion and form equally (18 observers), using motion more (31 observers), or using form more (27 observers). Performance on ADHD measures and survey scores for autism, empathy, and social anxiety were not correlated with performance on the biological motion tasks as measured by the slope of the logistic regression functions. There was a significant negative correlation between performance on the form only biological motion displays and vividness of movement imagery. Analysis of demographic data showed that females were more likely to be classified as "using form information more" or "using both motion and form about equally" while males were more likely to be classified as using "motion information more." These data show that there are individual differences on what information observers use to complete a sex identification task and these differences may in part be related to the sex of the observer and their visual movement imagery ability.

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23.327 **Evidence that low IQ, but not schizophrenia, impairs motion integration** Brian P Keane[1,2,3](brian.keane@gmail.com), Yujia Peng[4], Docia Demmin[2], Steven M Silverstein[1,2,3], Hongjing Lu[4,5]; [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]Department of Psychology, University of California, Los Angeles, [5]Department of Statistics, University of California, Los Angeles

Background. Prior studies have documented biological motion perception deficits in schizophrenia. Do these deficits arise from poor social cognition, perceptual organization, basic motion processing, or sustained attention? Methods. To address the question, we assessed 24 chronic schizophrenia patients and 27 healthy controls on three motion discrimination tasks: coherent motion, where subjects indicated whether a cloud of dots moved leftward or rightward; dynamic form, where subjects indicated whether a translating, point-dot rectangle was tilted leftward or rightward; and biological motion, where subjects judged whether a human point-light figure walked leftward or rightward. In all cases, task difficulty depended on the directional variability of the background dot motion. Thresholds were determined via an adaptive staircase procedure and corresponded to the amount of variability needed to generate 80% discrimination accuracy. Ten catch trials were additionally provided for each task to ensure that subjects were properly attending to the screen. To remove the possibility of group differences in button press errors, subjects provided verbal rather than button press responses. Results. Surprisingly, patients and controls demonstrated similar thresholds and also near-ceiling catch trial accuracy for all tasks (ps>.1, all ds< .35). Moreover, in all but the coherent motion task, higher IQ correlated with better performance (ps< .001); the effects were not moderated by subject group (ps>.09). Although patients as a whole were moderately symptomatic and disabled, symptom levels did not correlate with performance. Conclusion. These results suggest that schizophrenia patients have intact perception of motion coherence, dynamic form, and biological motion, at least when the experiment requires integrating local motion information to perceive global motion or shape. Prior studies may have identified deficits because of group differences in IQ or motivation, or because of task differences having to do with segmenting signal dots from noise.

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23.328 **Linking action words and body movements: Evidence from behavioral oscillations** Hannah Lee[1](leehannah@ucla.edu), Joseph Burling[1], Hongjing Lu[1,2]; [1]Department of Psychology, University of California, Los Angeles, [2]Department of Statistics, University of California, Los Angeles

There is growing evidence that motor regions are engaged not only in action execution and perception but also in action word comprehension. However, the underlying mechanisms connecting action perception and linguistic understanding remain unclear. The present study aims to examine the role of rhythmic processes in linking action-word comprehension with recognition of body movements from visual input. Rhythmic processes can be revealed by stimulus-locked oscillations in behavioral performance, reflecting the interactions between a current stimulus (i.e., probe action) and the state of ongoing activity elicited by a prior verbal stimulus (i.e., prime word), when manipulating the timing between prime and probe (stimulus onset asynchrony, SOA). In Experiment 1, participants viewed an uninformative (.5 predictive probability) action word (walk or run) for 500 ms. After a prime-to-probe SOA varying from 33 to 1500 ms with 25 levels evenly spaced in log-space, participants viewed an ambiguous point-light action morphed between a runner and a walker (with a morph weight of .7) for 400 ms. Fast Fourier transform on response times revealed reliable oscillatory patterns in the theta band (3-5 Hz) and alpha band (10-12 Hz). In Experiment 2, we increased the predictive probability of the action word to .67. SOAs were equally spaced in the range of 33 to 825 ms in increments of 33 ms. A facilitation effect was found when the word and subsequent action were congruent in comparison to the incongruent condition. We again found strong behavioral oscillations at theta and alpha bands, but with greater amplitudes than for the uninformative words used in Experiment 1. Our findings suggest that behavioral oscillatory effects do not only arise in low-level tasks, but also can be found in high-level visual tasks. Rhythmicity may serve as a core mechanism for binding distinct processes, such as action perception and linguistic meaning.

Acknowledgement: NSF BCS-1655300

23.329 **Investigating the Genetics Underlying Human Biological Motion Perception: a Genome-wide Association Study** Ren Na[1,2,3](naren2012@126.com), Biqing Chen[3,4], Zijian Zhu[3], Yi Rao[3,5], Fang Fang[1,2,3,5]; [1]School of Psychological and Cognitive Sciences 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]Jiangsu Province Hospital of Traditional Chinese Medicine, Affiliated Hospital of Nanjing University of Chinese Medicine, [5]PKU-IDG/McGovern Institute for Brain Research, Peking University, Beijing 100871, China

Biological motion perception is an essential ability of human visual system, which plays a major adaptive role in identifying, interpreting and predicting actions of others. Here we employed a genome-wide association method to examine the genetics of biological motion perception as a polygenetic cognitive trait. We measured the biological motion detection ability in a healthy cohort of Chinese population with normal or corrected-to-normal vision. Visual stimuli were point-light human walker figures. In the behavioral task, subjects were presented with two successive random motion dot animations and made a two-alternative forced choice (2AFC) judgment on which animation contained a point-light walker. We measured the average point-light walker detection accuracy for each subject. The behavioral performance showed substantial individual differences. We performed a genome-wide association study (GWAS) in a discovery cohort of 845 participants to identify biological-motion-detection-related variants. 125 common single nucleotide polymorphisms (SNPs) showing suggestive genomic significance ($p < 10\text{-}4$) were picked out for further replication in another cohort of 2102 Chinese people. 6 SNPs passed the replication study (nominal $p < 0.05$). Then we used functional magnetic resonance imaging (fMRI) to functionally validate these candidate SNPs in another cohort of 64 Chinese people. During viewing point-light walkers (relative to randomly moving point-light dots), the neural activity of the posterior superior temporal sulcus (pSTS) in the right hemisphere – a critical cortical area for biological motion processing – was taken as a phenotype. Results showed DGKD (nearest gene for SNP rs1053895) was associative with biological motion perception (nominal $p < 0.05$). Besides, SNP-based heritability was estimated to be 14.1% for biological motion detection ability. Evidence from this study indicates a mild contribution of genetics to human biological motion perception and suggests specific genes associated with it.

23.330 **Behavioral oscillations reveal hierarchical representation of biological motion** Yujia Peng[1](yjpeng@g.ucla.edu), 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

Human actions involve subparts of body movements nested within a hierarchical structure. However, numerous motion hierarchies are consistent with observed body movements. It remains unknown how the visual system identifies a particular hierarchic structure of body movements from visual input. To examine how multiple constraints interact to identify the hierarchy of body movements, and what mechanisms link different layers of the hierarchical representation, we used the behavioral oscillation paradigm, as stimulus-locked fluctuations in behavioral performance elicited by rhythmic brain activity. On each trial, moving limbs of a leftward or rightward walker, shown as a stick figure, were briefly presented for 100 ms. After an interstimulus interval (ISI) densely sampled from 0 to 1000 ms with 31 levels, participants viewed a point-light walker for 200 ms and judged its facing direction. Experiment 1 showed bipedal leg movements with opponent motions in the first stimulus; Experiment 2 showed arm-leg movements with opponent motions (as the arm and the

leg were on the same side of the body), and Experiment 3 showed arm-leg movements with the same motion direction (as the arm and the leg were on different sides of the body). An analysis of response times (RT) showed that bipedal leg movements yielded the strongest priming effect, with the subparts of body movements for the congruent walking direction facilitating recognition of the subsequent point-light walker. Fourier analysis of RTs revealed theta-band (3-7 Hz) oscillations for all three experiments. However, only sub-body movements with opponent motions in Experiment 1 and 2 elicited alpha-band (10-12 Hz) oscillations. Our results suggest that motion opponency plays an important role in determining the hidden layer of the hierarchical representation for walking actions, and that neural oscillation may serve as a key mechanism to bind layers of hierarchical representation for complex visual stimuli.

Acknowledgement: NSF BCS-1655300

23.331 **Combined Functional and Structural Mapping of Superior Temporal Sulcus** John A. Pyles[1,2](jpyles@cmu.edu), Emily D. Grossman[3], Austin I. Marcus[1], Michael J. Tarr[1,2]; [1]Department of Psychology, Carnegie Mellon University, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University, [3]Department of Cognitive Sciences, University of California, Irvine

The superior temporal sulcus is implicated in a wide range of visual and social perceptual processes: the perception of human motion, actions, animacy, speech, and faces, theory of mind, and the integration of audiovisual information. Many of these functions recruit overlapping regions in the STS while others elicit complex patterns of activation, making the functionality STS difficult to characterize. Our goal is to identify the core computations that connect these disparate functions, as well as better map how these functions are spatially distributed across STS. To address this long-standing question, we collected combined fMRI and dMRI within the same subject population across a broad range of stimuli and measures. Functional scans included: biological motion, social animacy, visual categories (faces, places, bodies, objects), motion, speech perception, multi-modal integration, and visual attention reorienting. White matter structural data was collected with high angular and spatial resolution diffusion imaging using a 253 direction multiband 2mm isovoxel DSI sequence. To compare our results with measures of intrinsic connectivity, we also collected resting state functional data. Our data also serves as a reference map for functional selectivity and structural connectivity of STS. To that end, we present our first mappings of functionally-identified regions on STS from this dataset. Activity on this map is consistent with previous reports, but here, with the functional and structural data in the same subject population: for example, more posterior activation for theory of mind relative to biological motion. Uniquely, we also map white matter structural connectivity in these subjects, seeding from functional ROIs, as well showing the relationship of STS connectivity with major tracts such as the inferior longitudinal fasciculus and the vertical occipital fasciculus. This large scale functional and structural STS dataset will lead to a more comprehensive characterization of STS's role in social perception and other cognitive processes.

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23.332 **The 'Blindfold Test' for Deciding whether an Effect Reflects Visual Processing or Higher-Level Judgment** Benjamin van Buren[1](vanburenb@gmail.com), Brian Scholl[1]; [1]Department of Psychology, Yale University

Beyond lower-level features such as color and orientation, visual processing also traffics in seemingly higher-level properties such as animacy and causality. For decades, researchers have studied these sorts of phenomena by asking observers to view displays and make subjective reports about such properties — e.g. "How alive does this dot look on a scale from 1-7?" Do these experiments measure observers' visual impressions, or merely their judgments that certain features should reflect animacy? (Even if you accept that we can truly perceive properties such as animacy, of course we can and do think about them as well.) Here we introduce the 'Blindfold Test' for helping to determine whether an effect reflects perception or judgment. The logic of the test is simple: If an experimental result can be obtained not only with visual displays, but also using written descriptions of those displays — i.e. without any visual stimuli at all (as if the subjects were wearing blindfolds) — then the fact that subjects attest in some way to seeing a property cannot (and should not!) be taken as evidence for visual processing of that property. Here we apply the Blindfold Test to two past studies. In the first study, subjects reported that moving shapes looked more animate when they increased their speed or changed heading. In the second study, subjects reported that shapes in a collision event appeared to exert less force when they 'shattered' into many pieces. To find out whether these results implicate visual processing per se, we reran these experiments while replacing the visual stimuli with (mere) descriptions. Both experiments' key findings replicated — in other words, they failed the Blindfold Test. As such, these studies do not license conclusions about perception, and this test may aid researchers interested in properly interpreting such results.

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23.333 **Perceiving animacy with causal constraints: A "leash resistance" effect in chasing detection** Haokui Xu[1](haokuixu.psy@gmail.com), Ning Tang[1], Jifan Zhou[1], Rende Shui[1], Mowei Shen[1], Tao Gao[2]; [1]Department of Psychology and Behavior Science, Zhejiang University, [2]Department of Statistics and Communication Studies, UCLA

Agents are not omnipotent. Instead, their motions are driven by both their internal intentions and outside constraints (such as an impulsive dog resisting its leash). In many cases, agents are even pulled away from their goals. How does vision interpret such intention-motion dissociations? One answer is that it simply can't, as suggested by studies showing that vision has little tolerance for deviations from perfect goal-directed motions (e.g. Gao et al., 2009). Alternatively, vision can detect intentions from deviated motions, provided it can explain away deviations as causal constraints imposed by the environment. We tested this hypothesis with the Search-For-Chasing task, in which a "wolf" pursues a "sheep" among distractors. The wolf's sheep-directed motion is compromised either by Causal or Non-Causal deviations. Causal deviations are generated by introducing the classic "motion hierarchy" phenomenon (Johansson, 1950) into a chasing display. The hierarchy puts the wolf on a virtual "leash", dragging the wolf away from the sheep-direction by composing the wolf's pursuit with the motion of its superior in the hierarchy. Non-Causal deviations are created by keeping the magnitude of the deviations while destroying the motion hierarchy. In Expt.1, both the wolf and sheep are constrained by a single superior, producing an averaged 45° deviation in the wolf's pursuit. Chasing detection is 21% higher with Causal deviations, compared to Non-Causal deviations. In Expt.2, the wolf is the subordinate of a distractor while the sheep flees freely, producing an averaged 65° deviation. The performance is again 20% higher with Causal-deviations. These results demonstrate that perceived animacy is more robust and flexible than previously suggested, provided the display can be explained by a causal hierarchical structure. We summarize it as a "leash resistance" effect, in which vision intelligently interprets intention-motion dissociations by jointly inferring the agent's internal intentions and outside causal constraints.

Perception and Action: Reaching and grasping

Saturday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

23.334 **Getting started with the MOTOM toolbox – an Optotrak-Matlab interface: From the first beeps to fingertip tracking in virtual reality** Zoltan Derzsi[1](zd8@nyu.edu), Robert Volcic[1]; [1]New York University Abu Dhabi

The Optotrak is a motion capture system which has been widely used in the past two decades in both industry and academia. Here we present a Matlab toolbox that allows users to initialise hardware and automate data collection. With previous Matlab-Optotrak interfaces, the user was required to manually compile C code in an external integrated development environment. The MOTOM toolbox does the vast majority of the initialisation and setting-up process, without the need of human interaction and programming skills once all the software requirements are met. It works on both 32 and 64-bit systems. The toolbox also detects the configuration of the hardware it is controlling: it can automatically assign many cameras together, and it can monitor memory usage and

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read diagnostic information. We present a number of code examples and what we perceive as best practices to allow fast, convenient and reliable data acquisition. In addition to the core features such as rigid body tracking which handles a number of assigned markers together as a single entity, we introduce additional functions that are frequently used in the day-to-day life of an experimenter, such as proximity detection, the automated creation of rigid body definitions, or the handling of virtual markers (coordinates calculated with respect to a rigid body). Virtual markers are especially useful when placing a physical marker on a particular body segment is impossible; they can be used to track the tips of fingers or the nodal points of the eyes. We present our implementation of fingertip tracking, to demonstrate the use of custom-built rigid bodies and the general capabilities of the MOTOM toolbox. The MOTOM toolbox can be used in conjunction with other toolboxes, which makes it a valuable addition to studies where obtaining position information is required: digitising 3D objects, studying grasping/reaching, calligraphy or virtual reality environments.

23.335 **Adjusting visual illusions for differential sensitivity to target size decreases the likelihood of differentiating action from perception.** Patrick J. Laflamme[1](patrickj.laflamme@gmail.com), Robert L. Whitwell[1], James T. Enns[1]; [1]Psychology, University of British Columbia

Vision researchers have relied on compelling pictorial illusions to argue both for dissociations between action and perception (multiple visual-systems – MVS - proponents) and against them (common visual system – CVS - proponents). A methodological issue that divides these researchers is whether the effects of illusions on action and perception should be adjusted for baseline differences in sensitivity to size, prior to making the comparisons. Here we use Monte-Carlo simulations to explore how adjusting for the response sensitivity function influences the comparison of illusion effects across response modes. We generated data from multivariate distributions based on typical parameters reported in the literature, before adjusted the effects of the illusion using three techniques: index, zero variance, and a Taylor-approximated application of Fieller's theorem. For each unique combination of parameters, we contrasted pairs of unadjusted and pairs of adjusted illusion effects and computed the observed Type I error (alpha) and II error (beta) values. We used a pseudo d' measure to incorporate both alpha and beta into a single metric of efficiency. The zero variance method yielded a small pseudo d' with unacceptably high alpha. The index method yielded the smallest pseudo d', with a moderate alpha combined with high beta. Among the adjustment methods, Fieller's method yielded the best control over alpha, but at the cost of increased beta. When alpha and beta rates were considered together, unadjusted measurements were, surprisingly, the most efficient. Our findings warrant two recommendations: 1) the Fieller-adjusted effects of the illusion in a given response mode are preferable to other adjustment methods; and 2) the unadjusted effects of the illusion should be used to compare between response modes. These analyses imply that ongoing debates between proponents of MVS and proponents of CVS should be based on unadjusted measures of the same illusion for each response mode.

23.336 **Stereoacuity predicts total movement time in a fronto-parallel prehension task** Angelica Godinez[1](angelica_godinez@berkeley.edu), Alyson L Kishi[1], Mariela E Hernandez[1], Preeti Verghese[2], Dennis M Levi[1]; [1]School of Optometry, University of California, Berkeley, [2]The Smith-Kettlewell Eye Research Institute

Spatial and binocular vision play an important role in visuomotor control and execution (Melmoth & Grant, 2006). However, people who are stereoblind or -anomalous exhibit deficits in spatial vision, which consequently impacts the way they interact with objects in the environment (Grant, Melmoth, Morgan, & Finlay, 2007). Although the role of binocular vision on hand-eye coordination has been a topic of research interest (Melmoth & Grant, 2006; Grant et al., 2007; Melmoth et al., 2009), and observational results suggest that the total movement time increases with the amount of disparity sensitivity loss (Melmoth et al., 2009), the direct relationship between stereopsis and prehension in a stereo-anomalous population has not been quantified. Thus, the aim of this study was to quantify the relationship between stereoacuity and motor movement using a prehension task with a fronto-parallel view (Verghese, Tyson, Ghahghaei, & Fletcher, 2016) to most accurately test the influence of binocular vision. We tested 15 observers with varying binocular alignment (7 normal, 2 anisometropic, 2 strabismic, 4 mixed) and stereoacuity (31 to >1500 arc secs) on a peg-placement prehension task. Each observer completed a total of 16 trials for each viewing condition (DE, NDE, and binocular). Stereoacuity measures were taken from the Asteroid software, which is a 4-AFC Dynamic Random Dot stimulus with a Bayesian staircase, presented on the FlightDeck tablet. 3D tracking of the wrist, thumb and grasping finger was captured at 240 Hz with the Polhemus Liberty 240/16 motion tracker. Our preliminary results indicate that stereoacuity is positively correlated with the total movement time on the task ($r = 0.46$, $p < 0.05$). Consistent with previous studies, our results show that there is an advantage of binocular viewing compared to dominant eye viewing. We conclude that stereoacuity is an important factor in everyday hand-eye coordination

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23.337 **Visuomotor adaptation is sensitive to perceptual changes in depth information** Carlo Campagnoli[1](carlo.campagnoli@princeton.edu), Jordan A Taylor[1]; [1]Department of Psychology, Princeton University

Visuomotor adaptation has been traditionally explained as the gradual update in an internal model based on a visual discrepancy between an intended movement and the resultant outcome. Under this framework, it has been assumed that the input to the motor system depends uniquely on a veridical estimate of the metrical properties of the scene. However, this assumption contrasts with many studies showing that action reflects biased estimates of 3D information. Whereas these distortions can cause problems for action, rapid motor adaptation helps overcome them. Yet, it remains unclear if adaptation itself relies on an accurate analysis of depth. Here, we tested whether motor learning processes were sensitive to changes in 3D information despite the same visual error which was being presented. Subjects reached to a visual target (a 6 degrees wide circle) that was either alone (No-depth condition) or surrounded by a virtual environment (Depth condition). To induce visuomotor remapping we imposed a task-irrelevant-error clamp: Regardless of the actual hand's direction, the cursor always hit off the target by a fixed horizontal offset. Although this visual error was irrelevant for the task, subjects displayed robust adaptation: They moved in a direction opposite of the visual error induced by the clamp. Furthermore, this motor learning was stronger in the No-depth condition compared to the Depth condition. Remarkably, these results mirrored those of a perceptual task, where subjects adjusted distance and width of a probe to match the target's perceived location and size under the same two visual conditions. That is, the degree of adaptation was sensitive to perceived depth. These results demonstrate that visuomotor adaptation takes into account a more sophisticated error signal than previously thought, integrating also sources of information that are irrelevant to the task

23.338 **The effect of losing or gaining visual information on movement performance when reaching for haptic targets.** Ivan Camponogara[1](ivan.camponogara@nyu.edu), Robert Volcic[1]; [1]Department of Psychology, New York University Abu Dhabi

Precision of goal-directed aiming movements toward visuo-haptic targets is generally higher than toward visual or haptic only targets. However, the role of each modality in visuo-haptic reaching is still unknown. In the present study, we investigated how removing or providing visual information during a reaching movement toward a haptically perceived target modulates precision (end point variability). Participants were asked to perform rapid and accurate reaches to the top of three cylinders (diameter: 10, 25 and 35 mm, height: 50 mm) located 200 mm from the starting position. In one block, vision and haptics were always available before reach initiation and during the whole movement (HV), whereas in the other block, only haptics was available (H). However, in both blocks, on half of the trials, vision was suddenly removed (HV-) or added (HV+) during the reaching movement. These perturbations occurred at the 25% or 50% of the movement. Precision was highest in HV and worst in H. However, while removing vision at different points of the hand path (HV-) had a slight worsening effect on precision, adding it (HV+) strongly improved precision, without, however, ever reaching the HV or HV- level. Interestingly, while movement time did not depend on the initial sensory conditions, time to movement onset was longer in H and HV+ than in HV and HV-, indicating a longer movement planning phase when only haptics was available during movement preparation. Our findings show that integrating visual and haptic sensory information during the planning phase leads to much better action performance compared to when the senses are integrated on-line, even when vision is provided in the very early stages of the movement. Thus, when haptic information is strengthened by an early visuo-haptic sensory integration, preventing on-line visual feedback has only minor repercussions on movement performance.

23.339 **Sensory feedback reduces scalar variability in grasping** Ailin Deng[1](dengailin@gmail.com), Evan Cesanek[1], Fulvio Domini[1]; [1]Department of Cognitive, Linguistic, & Psychological Sciences, Brown University

Visual perception of spatial properties obeys Weber's law: variability in the perceptual response scales with the physical stimulus magnitude. Yet some recent studies have shown that motor responses (e.g., the grip aperture of grasping movements) do not show this scalar variability effect. It remains an open question whether the absence of scalar variability in motor responses is due to visual processing that does not obey Weber's law or if it is due to other unaccounted-for factors. Since visual and haptic feedback are known to calibrate the accuracy of reach-to-grasp movements over repeated trials, we hypothesized that sensory feedback from repeated movements may also reduce scalar variability. In virtual reality, participants repeatedly reached-to-grasp visual targets of varying lengths (21-42 mm) along their vertical axes, and we analyzed within-subject variability in maximum grip apertures (MGAs) and in grip-aperture trajectories. We manipulated feedback availability in four blocks: no feedback, visual feedback only, haptic feedback only, or visual and haptic feedback. When visual feedback was available, participants could see their fingertip positions as the hand approached the target. When haptic feedback was available, participants encountered a physical object that matched the visual target. Our results demonstrate that sensory feedback does reduce scalar variability. We observed strong scalar variability in the no-feedback condition, both in early stages of the movement and at the terminal grip aperture. In all other feedback conditions, scalar variability was reduced across the entire movement. Notably, the fact that visual feedback alone reduced scalar variability just as much as haptic feedback indicates that the presence of haptic feedback is not critical for calibration to occur. In follow-up trajectory analyses, we explored whether various models of grasp planning could explain our results. We conclude that scalar variability in the grip aperture arose from motor processes, not the visual size estimation process.

23.340 **How do vision and haptics combine in multisensory grasping?** Robert Volcic[1](robert.volcic@nyu.edu), Ivan Camponogara[1]; [1]Department of Psychology, New York University Abu Dhabi

The ability to visually localize an object and perceive its shape is essential to execute successful grasping movements. However, the haptic sense can also provide valuable information about the object's position and shape when touching an object with the hand. Here we investigate if grasping actions toward objects that are simultaneously seen and touched are more efficient than those under unimodal guidance. Moreover, we identify which haptic object properties (position and/or size) play the major role in multisensory grasping. Participants (n = 20, 6000 total trials) performed grasping movements toward five differently sized objects ranging from 30 mm to 70 mm located at three egocentric distances. In the visual condition (V), participants had full vision of the object and the workspace. In the haptic condition (H), vision was prevented and the action was under the guidance of haptic information from the other non-grasping hand. In the visuo-haptic condition (VH), both visual and haptic information were available throughout the movement. In an additional visuo-haptic condition (VHp), participants held a post which supported the object, instead of holding the object itself, while vision was fully available. In this case, haptics was informative only about the position of the object, but not about its size. Participants opened their hands wider in the H condition than in the V condition (92 mm vs. 86 mm). The multisensory advantage was clear in the VH condition: the maximum grip aperture was considerably smaller (81 mm) and movements were 125 ms faster than in the unisensory conditions. Critically, in the VHp condition, in which participants had full vision of the object, but only positional haptic information, grasping movements were as efficient as in the VH condition. We conclude that haptic position, not haptic size, is merged with visual signals when grasping movements are directed toward multisensory objects.

23.341 **Grasping modulates unconscious processing of manipulable objects** Wenyuan Yu[1,2](yuwy@psych.ac.cn), Ye Liu[1,2], Xiaolan Fu[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Psychology, Chinese Academy of Sciences, [2]Department of Psychology, University of Chinese Academy of Sciences

Manipulable objects could be processed by dorsal stream under continuous flash suppression (CFS) while nonmanipulable objects could not (Fang & He, 2005). Previous research showed that category congruent primes under CFS facilitated the categorization of manipulable objects, but not that of nonmanipulable objects, which inferred that category information of manipulable objects could be unconsciously processed by dorsal stream (Almeida, Mahon, Nakayama, & Caramazza, 2008). But recent research found that elongated-shaped primes, regardless of their categories, facilitated the categorization of manipulable objects, which suggested that it was elongated-shape, not category information, that processed by dorsal stream in unconscious condition, and it might be explained that elongated-shaped stimuli were always graspable, which was sufficient to affect the categorization (Almeida et al., 2014). However, it was unknown whether manipulability based on the affordance of elongated shape could be unconsciously processed in dorsal stream. In the present study, a breaking-CFS experiment was conducted to explore whether grasping could affect the unconscious processing of manipulable objects. Object images with contrast ramped up gradually from 0 to full contrast within 1 second were presented in nondominant eye, whereas CFS stimuli were presented in dominant eye. Participants were asked to judge the object location by left hand as quickly and accurately as possible, with their right hand grasping a model in a dark box. The volume of model might be congruent or incongruent with the actual volume of the objects in images. The result showed that the suppression time of the object images was significantly shorter when participants grasped the models whose volume were congruent with the suppressed objects than those whose volume were incongruent with the objects. It suggested that grasping modulation of manipulable object processing occurred in the absence of visual awareness, and it might be manipulability, not elongated shape, that could be processed by dorsal stream in unconscious condition.

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23.342 **Active visuomotor interactions with virtual objects are intruded by perceptual processing** Aviad Ozana[1](ozanaaviad@gmail.com), Tzvi Ganel[2]; [1]Ben-Gurion University of the Negev, [2]Ben-Gurion University of the Negev

Recent findings suggest that the functional separation between vision-for-action and vision-for-perception does not generalize to situations in which 2D objects are used as targets. For example, unlike as in real, 3D grasping, trajectories during 2D grasping adhere to the psychophysical principle of Weber's law, implying atypical, relative processing of object's size. A potential account for this failure in selectivity during 2D grasping is that typical interactions with virtual objects on touchscreens involve unique gestures other than grasping, in which the virtual objects are dynamically controlled. Here, we explored whether typical, active visuomotor interactions with virtual objects on touchscreen could enable analytic processing. In Experiment 1, we focused on "swiping" gestures, in which participants were asked to touch the edges of the virtual object and to slide it across the screen. In the dynamic condition, the target object followed the location of the fingers. In the static condition, the target object remained in the center of the screen. In both conditions, movement trajectories showed a similar pattern of adherence to Weber's law. In Experiment 2, we examined another typical type of a visuomotor interaction with virtual objects, in which participants were asked to increase the size of the virtual object using "spreading" gestures. One again, movement trajectories adhered to

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Weber's law. Taken together, the results suggest that active interactions with virtual objects on touchscreen are not subserved by the typical, analytic processing style that characterizes typical 3D grasping, and are intruded by irrelevant perceptual information.

23.343 **Semantics determine the influence of allocentric information in memory-guided reaching** Harun Karimpur[1](harun.karimpur@psychol.uni-giessen.de), Katja Fiehler[1]; [1]Experimental Psychology, Justus Liebig University Giessen

Interacting with objects is a complex task that requires us to mentally represent spatial configurations in our environment. It is well established that we encode objects for action in both egocentric and allocentric reference frames, i.e. relative to our own body or to other objects, respectively. Known factors that determine the influence of allocentric information are contextual factors such as scene configuration (e.g., spatial object clusters) and task-relevance. While the former concerns aspects of the spatial layout, the latter concerns higher level factors. In this study, we investigated whether objects that are not spatially but semantically clustered also influence the extent to which humans rely on allocentric information. To this end, we conducted a memory-guided reaching task in virtual reality. We used six objects from two different semantic clusters and placed them on a table. Participants encoded the objects while they were allowed to freely explore the scene. After a brief mask and a delay, the scene was shown again (test scene) for a short duration with one object missing. Participants were asked to reach to the location of the missing object (reaching target) from memory on an empty table. In the test scene, two objects which either belonged to the same (congruent) or a different (incongruent) semantic cluster as the reaching target were shifted horizontally. In the baseline condition, no object shift occurred. The results show that reaching endpoints deviated in the direction of object shifts. More importantly, these errors were larger when semantically congruent as opposed to incongruent objects were shifted. We argue that humans integrate higher-level information when interacting with objects. Semantic clustering could be an efficient mechanism of representing objects for action. Further experiments should investigate different levels of semantics and similarities between objects.

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23.344 **Visual-motor mapping in VR: Detection thresholds for distortions of hand position** Siavash Eftekharifar[1,2](16se16@queensu.ca), Niko Troje[1,2]; [1]Dept. of Psychology, Queen's University, [2]Centre for Neuroscience Studies, Queen's University

Using head-mounted virtual reality systems in which haptic feedback is provided by matching objects of the real world with objects of the virtual word, the demand on the accuracy of the mapping between virtual and real space depends on the accuracy of the visual-motor mapping of the user's sensorimotor system. Using a system that consists of an Oculus DK2 head-mounted display and the LEAP motion controller, by which participants can see renderings of their hands, we probed the tolerance of participants to distortions of the mapping between motor space and visual space. Participants were asked to keep their open hands symmetrically in front of them such that the two thumbs were close, but without touching each other. We then manipulated the visual-motor mapping in two different ways by either introducing a linear, homogenous translation of both hands, or a nonlinear transformation, which corresponds to a compression or expansion of the space between the two hands. Using this technique we moved their hands in one of six (2 x lateral, anterior-posterior, vertical) directions and asked them to indicate which one it was. The detection threshold was determined as the displacement at which they were correct in 58% (1/6 + 0.5* 5/6) of the cases. A 2x3 ANOVA (condition x direction) revealed a main effect of condition ($F(1,54)=75$, $p< 0.001$). Participants are more sensitive detecting the relative displacement of the hands (4 cm) than their absolute location in space (5.3 cm). Knowing detection thresholds informs the design of haptic devices for mixed VR since it determines the tolerance of users to the amount of displacements between real and virtual objects. The results also suggest that the coordination of relative positions of hands is more accurate compared to the absolute .location.

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23.345 **Visually guided unimanual and bimanual reaching rely on different cognitive mechanisms: Evidence from optic ataxia** Celia P Litovsky[1](litovsky@jhu.edu), Feitong Yang[2], Zheng Ma[3], Jonathan Flombaum[2], Michael McCloskey[1]; [1]Department of Cognitive Science, Johns Hopkins University, [2]Department of Psychological and Brain Sciences, Johns Hopkins University, [3]Smith-Kettlewell Eye Research Institute

Although most visually guided actions require coordination of both limbs, the vast majority of research on reaching focuses on reaching with a single hand. In order to investigate whether unimanual (single-hand) and bimanual (two-hand) reaching rely on different cognitive mechanisms, we tested optic ataxic patient MDK on a series of tasks of unimanual and bimanual reaching to peripheral visual targets. Targets were presented in MDK's visual periphery and he immediately pointed either to the left side of each target with the left hand, the right side of each target with the right hand, or to both sides of each target with both hands simultaneously. If bimanual reaching involves simply performing two unimanual reaches simultaneously, we would expect no difference in performance on bimanual and unimanual reaching. In fact, however, we observed significantly better performance in bimanual than in unimanual reaching. In unimanual reaching MDK's points with either hand typically undershot the target by more than half its eccentricity ($p < 0.001$); that is, he systematically pointed far too close to fixation. However, MDK's bimanual points to these same targets showed significantly less undershooting ($p < 0.001$). The dissociation between MDK's unimanual and bimanual reaching behavior indicates that unimanual and bimanual pointing may involve different cognitive mechanisms. We suggest that bimanual, but not unimanual, pointing involves using the distance between two targets as a basis for determining the distance between the pointing hands. MDK's relatively accurate representation of the distance between two peripheral targets allows him to point more accurately (i.e., with less fixation-bias) for bimanual compared to unimanual reaching. This dissociation between unimanual and bimanual reaching may therefore arise because of additional computation of the distance between two targets during bimanual, but not unimanual, reaching.

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23.346 **Beyond sensory processing: Human neuroimaging shows task-dependent functional connectivity between V1 and somatomotor areas during action planning** Jena Velji-Ibrahim[1,2,3,4,5](jenav@my.yorku.ca), J. Douglas Crawford[1,2,3,4,6], Simona Monaco[1,5]; [1]Centre for Vision Research, York University, Toronto, Ontario, Canada, [2]Vision: Science to Applications (VISTA) Program, York University, Toronto, Ontario, Canada, [3]Department of Kinesiology and Health Science, York University, Toronto, Ontario, Canada, [4]Neuroscience Graduate Diploma Program, York University, Toronto, Ontario, Canada, [5]Center for Mind/Brain Science, University of Trento, Trento, Italy, [6]Departments of Psychology, Biology, York University, Toronto, Ontario, Canada

To execute actions in daily life successfully, our brain needs to process information about the orientation and location of a target object. Previous studies have found that the activity in the early visual cortex can be used to predict upcoming actions (Gutteling et al., 2015; van Elk et al., 2010). These findings suggest that the early visual cortex is functionally connected to higher-level cortical areas involved in action preparation. To explore this, we examined whether the primary visual cortex (V1) is connected to motor and somatosensory areas in a task-dependent manner during action planning. We used a slow event-related fMRI paradigm in which participants (N=16) performed actions with their right hand towards two objects placed on either side of a fixation cross. The object on the right and left were oriented at 45° and 135°, respectively. At the beginning of each trial, an auditory cue indicated the action type (Align Hand right, Align Hand left, Open Hand right, Open Hand left). A delay of ten seconds was followed by a go cue for action execution. Standard retinotopic mapping procedures were used to identify the boundaries of V1. While Align movements required participants to adjust their hand precisely according to the orientation of the object, Open Hand movements were coarse. Therefore, we hypothesized enhanced functional connectivity between V1 and areas involved in motor planning during

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the Align as compared to the Open Hand task. As predicted, psychophysiological interaction analysis showed a stronger functional connectivity between V1 with dorsal stream and somatomotor areas including primary motor and somatosensory cortex (M1/S1) during planning for the Align versus Open Hand tasks. These connections may play a role in the anticipation of the visual consequences of movement execution during action planning.

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23.347 **Decoding the electrophysiological dynamics of visual-to-motor transformations during grasp planning and execution** Lin Guo[1](linn.guo@mail.utoronto.ca), Adrian Nestor[1], Dan Nemrodov[1], Matthias Niemeier[1,2]; [1]University of Toronto Scarborough, [2]The Centre for Vision Research, York University

The time course of visuomotor transformations of human grasp actions remains largely unclear. For instance, the informativeness of electroencephalography (EEG) data is limited both because of the anatomy of the visuomotor cortex and because of the traditional emphasis on univariate effects in EEG investigations. Here, we applied classification techniques to spatiotemporal EEG patterns to characterize the electrophysiological dynamics of visuomotor processes during grasp planning and execution. To this end, we recorded from 64 channels while participants used their right dominant hand to grasp 3D objects with two kinds of shapes and textures, using two different grasp orientations. Each trial encompassed three relevant events; a 200ms Preview of the object followed by a variable delay in darkness, a Go period during which the object re-appeared indicating that participants should move to grasp it, and a Movement onset period. After aligning event-related potentials (ERPs) with each event we attempted to classify visual object features (i.e., different object shapes or different textures) based on all channels across ~10ms temporal windows. Our results show that texture classification was poor throughout, but shape classification was robust, peaking at ~100ms after Preview onset and slowly declining during darkness. The Go period showed a similar shape classification curve, but around Movement onset the curve remained close to chance level. Interestingly, classification of shape combined with grasp orientation, while roughly similar during the Preview and Go periods, ramped up before Movement onset, and a similar curve was found for texture-by-grasp classification. Finally, grasp orientation regardless of object features was successfully decoded during Preview, yet it ramped up to higher levels during the Go period, and prior to Movement onset. These results reveal the progression of visual to visuomotor and motor representations over the course of planning and executing grasp movements as reflected in the dynamics of electrophysiological signals.

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23.348 **Decoding action intention from the activity pattern in the Foveal Cortex** Simona Monaco[1](simona.monaco@gmail.com), Giulia Malfatti[1], Laura Pizzato[1], Luigi Cattaneo[1,2], Luca Turella[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy, [2]2. Department of Neurological, Neuropsychological, Morphological, and Movement Sciences, University of Verona, Italy

The human early visual cortex comprises feedback projections from higher-level cortical areas that profoundly affect perception. However, little is known about how the preparation of actions modulates the activity in the early visual cortex. To this explore this, we used a slow event-related functional magnetic resonance imaging (fMRI) paradigm in which participants (N=16) performed actions with the right dominant hand towards a centrally-located 3D-real-object. We manipulated the availability of visual information (Vision or No Vision) and the action type (Grasp or Open hand). In the Vision condition, participants fixated the object. Actions consisted of grasping the object or moving the open hand towards the object without interacting with it. At the beginning of each trial an auditory cue instructed participants about whether to close their eyes and the action to be performed at the end of the trial. A 10-s delay was followed by the go cue. We used retinotopic mapping standard procedures to localize the Foveal Cortex and identify the boundaries of the Primary Visual Cortex. With multivoxel pattern analyses we examined whether the activity pattern in the Foveal Cortex could be used to decode action intentions (Grasp or Open hand) during the planning phase preceding the action. Our results show successful decoding in the Foveal Cortex for the dissociation between action types (Grasp vs. Open hand) in Vision as well as in No Vision conditions. However, the activity pattern in Vision condition cannot be used to successfully decode the dissociation between action types in the No Vision condition, and vice versa. In addition, the decoding accuracy is higher in Vision than No Vision condition. These findings indicate that action planning modulates the activity patterns in Foveal Cortex even in absence of visual information, and suggest predictive coding related to action regardless of the availability of Visual information.

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23.349 **Strong optic flow enables accurate and stable perception of metric shape despite blurry vision** Yani Chen[1](chenyn223@mail2.sysu.edu.cn), Jing Samantha Pan[1]; [1]Sun Yat-sen University

Defined as the depth/width aspect ratio, metric shape is perceived when an object makes ≥45° continuous rotation in depth (Bingham & Lind, 2008). In this case, two sources of information are available to an observer: optic flow and image structure. Through motion—low spatial frequency signals—optic flow specifies depth structures and allows shape perception. Therefore, with strong optic flow, metric shape should be perceptible even when vision is blurred. Furthermore, when an object rotates, optic flow also calibrates image structure to make it spatiotemporally meaningful. In return, calibrated image structure preserves the depth structures specified by optic flow after motion ends. The combination of optic flow and image structure has been shown to engender efficient perception of object locations (Pan, Bingham, & Bingham, 2013, 2017) and daily events (Pan & Bingham, 2013), and is expected to enable accurate and stable perception of metric shape. We tested these predictions in two experiments. In Experiment 1, we used 0.2 Bangerter filters to create blurry vision and found that when target objects were rotating 60° back and forth, their metric shapes were accurately perceived by observers with or without the filters. In Experiment 2, observers with or without the filters viewed a random target object rotating 60° and waited for 0s, 5s, 15s, 25s, or 35s before they adjusted an outline on the monitor to match the cross-section of the target object. During the delay, observers either saw the stationary target object or a black screen. Errors were smaller when the image structure of target object remained available during the delay. In conclusion, we found that perception of metric shape is accurate and stable with strong optic flow, even when image structure is impaired. The findings are applicable to low vision rehabilitation, especially in regaining visual functions (such as visually guided grasping) with blurry vision.

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Perceptual Organization: Ensembles, averaging, numerosity

Saturday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

23.350 **Ensemble-based segmentation in the perception of multiple feature conjunctions** Vladislav A Khvostov[1](hvo100v@mail.ru), Igor S Utochkin[1]; [1]Laboratory for cognitive research, N.R.U. Higher School of Economics

In everyday perception, we are surrounded by large numbers of objects with variable features. Instead of interpreting this variety as completely different objects, we can quickly categorize them as belonging to one or several types (e.g., berries and leaves). We suggested earlier that such categorization can be based on ensemble statistics: The visual system "decides" whether the overall feature distribution has one or more "categorical" peaks. We have tested this theory for unidimensional feature distributions (Utochkin & Yurevich, 2016). Here, we test it for conjunction-defined ensembles. In three experiments, observers discriminated between two textures filled with lines of various lengths and orientations. Length and orientation had same distributions in the textures, but their correlations were opposite. The crucial manipulation concerned the shapes of feature distributions: They could be "segmentable" (only

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extreme feature values presented with a large gap between them), or "non-segmentable" (both extreme and middle values presented with smooth transition between). In Experiment 1, we found that segmentable displays yield steeper psychometric functions indicating better discrimination. In Experiment 2, we found that the effect of segmentability on texture discrimination occurs at 100-200 ms and requires both feature dimensions having a "segmentable" distribution. We interpreted this in terms of "preattentive" division of the textures into categorical classes of conjunctions. That is, the visual system (1) divides the set into subgroups based on highly distinctive peaks, (2) selects all items from one of the peaks, and (3) decides whether a second dimension also forms two peaks across textural patches. In Experiment 3, we tested a hypothesis that imperfect selection of a subset at step (2) is an important limiting factor of accurate categorization. When a half of lines from one side of one of the feature distributions were removed, discrimination using the remaining feature distribution was much better.

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23.351 **Effect of spatiotemporally changing environment on serial dependence in ensemble representations** Son Sangkyu[1](sporrr@hanmail.net), Kim Yee-Joon[1]; [1]Center for Cognition and Sociality, Institute for Basic Science (IBS), Daejeon, South Korea

Serial dependence promotes perceptual stability by integrating similar features of successive stimuli over time. A Recent study demonstrated serial dependence in ensemble representations. This suggests that our visual system tends to represent sets of similar items as statistical summaries across both space and time. We investigated if such temporal smoothing process would be disrupted when ensemble variability changes over time. Observers were asked to adjust the average orientation of an array of 16 randomly oriented Gabors in the peripheral visual field. Each array had either high (H) or low (L) standard deviation. There were two neutral sessions with random stimulus sequence of H and L and two repetitive sessions with stimulus sequence of either L or H. We analyzed serial dependence for the nearest sequential pair in each session. Serial dependence was observed in L stimulus regardless of previous stimulus variability. Serial dependence was also observed in H stimulus when the previous stimulus had H. However, the negative bias was observed in H stimulus when the previous stimulus had L. Internal expectancy of ensemble variability might cause this negative bias in LH pair. It might be the case that internal transition probability from L to H would be smaller than actual stimulus transition probability(≈0.5), making LH pair less predictable. To test this hypothesis, Hidden Markov Model was fitted to the behavioral errors categorized into H and L group. HMM showed that LH transition probability was significantly smaller than 0.5. More importantly, negative bias in LH pair was stronger for unpredicted trials, while predicted trials did not show negative bias. These results suggest that unpredictably increased variability makes sensory system adaptive to maximize change sensitivity by negatively biasing away from previous ensemble representation.

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23.352 **Reciprocal Interference between Global and Local Processing in Ensemble Perception** Dilakshan Srikanthan[1](dilakshan.srikanthan@mail.utoronto.ca), Marco A Sama[1], Sol Z Sun[1], Adrian Nestor [1], Jonathan S Cant[1]; [1]Department of Psychology, University of Toronto Scarborough

The ability to represent multiple objects via a statistical summary is known as ensemble encoding. While humans can rapidly extract a summary feature from an ensemble of objects (e.g., mean orientation), representations of single objects may be considerably less accurate. Moreover, research has shown that single-item representations are biased towards the mean, which is consistent with the dominance of global over local processing (Navon, 1977). Despite this, the influence of local information on global processing is apparent in object-scene interactions (Lowe et al., 2015). Given the relationship between ensemble processing and scene perception (Cant & Xu, 2015), we investigated relationships between global and local processing utilizing a novel ensemble-interference paradigm. Participants were shown eight oriented triangles and instructed to remember their orientations. In a subsequent 2AFC task, a target and distractor were presented, and participants reported either the average orientation (global condition) or the orientation of a randomly selected single triangle (local condition). Additionally, we manipulated the degree of interference from the distractor. In the global condition, the distractor was either a non-target triangle from the studied set (high interference), or a novel triangle (low interference). Similarly, in the local condition, the distractor was either the mean of the set (high interference) or a novel triangle (low interference). When the mean was presented as the distractor in the local condition, participants were more likely to report it as the single target item, but were above chance at reporting the single item when the mean was not presented. Interestingly, we also observed local-to-global interference wherein single items from the set in the global condition biased representations of the mean. Thus, even though global features were reported more accurately and caused greater interference, we observed reciprocal interference between global and local processing, which is consistent with what is observed in object-scene interactions.

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23.353 **Ensemble perception of centers of inferred shapes vs. centers of item positions** Matthew S Cain[1,2](matthew.s.cain6.civ@mail.mil), Sasen S Cain[3], Dawn M Wendell[4]; [1]U.S. Army, Natick Soldier Research & Development Center, [2]Tufts University, Center for Applied Brain & Cognitive Sciences, [3]University of California San Diego, Department of Psychology, [4]Massachusetts Institute of Technology, Department of Mechanical Engineering

Estimating average properties of ensembles is important when there is a need to act upon the ensemble, such as controlling the movement of a swarm of semi-autonomous agents. We explored observers' accuracy in perceiving both the center of the gestalt global shape and the average item position of ensembles of dots. Ensembles of 12, 18, or 24 dots were drawn within an invisible circle, with half on the perimeter. In separate blocks, we instructed participants to click on the Center of the Inferred Shape (i.e., the origin of the circle) or the Center of the Dot Positions (i.e., the average position). Baseline trials were constructed such that the two centers were identical. Test trials were constructed by modifying baseline ensembles, displacing single test dots to dissociate the Center of the Dot Positions from the Center of the Inferred Shape. On Baseline trials, participants were more accurate clicking the Center of the Inferred Shape (mean error 27.7 pixels) than the Center of the Dot Positions (17.3 pixels, $p < .01$), with no difference in response time ($p > .05$), suggesting that finding the center of the gestalt global shape is relatively easier. For Test trials in the Center of the Dot Positions condition, error increased with test dot distance from the center, but less so for perimeter test dots, suggesting greater focus on internal items. Conversely, for the Center of the Inferred Shape, perimeter test dots increased error, while test dots in the interior did not, suggesting greater perimeter item focus. Overall, participants were better at finding the Center of the Inferred Shape than the Center of the Dot Positions and this perception was more robust to changes to internal ensemble items, but more vulnerable to changes to the perimeter items.

23.354 **Ensemble Statistics are (only) Accessed through Proxies: Range and Spatial Texture Heuristics in Variability Discrimination** Jonas S.-H. Lau[1](silau@ucsd.edu), Timothy F Brady[1]; [1]Psychology, University of California, San Diego

Ample evidence has shown that people are sensitive to the mean size and the variability of a set of items in a display (Ariely, 2001). Through simulations, we show that neither parallel access to all items (e.g., Chong & Treisman, 2003) nor random subsampling of just a few items (Myczek & Simons, 2008) is sufficient to allow accurate estimations of size variability. In four experiments, we examined how variability discrimination is achieved. Participants compared two arrays of circles with different variability in size. In the first 2 experiments, we manipulated the congruency of the range (smallest and largest items) and the variance of the two arrays. We showed that participants were more accurate when range and variance conveyed congruent information. This indicates a reliance on range as an approximation for variability [Experiment 1: $F(1,33)=28.5, p< 0.001$; Experiment 2: $F(1,42)=6.7, p=0.01$]. In Experiment 3, we replicated Experiment 2 using outlined, instead of filled, circle displays. By removing most of the texture information from the filled circle displays, we showed that the range heuristic is a general one, being utilized in different scenarios [$F(1,31)=11.4, p< 0.002$]. In Experiment 4, we directly tested the use of texture information on variability discrimination. On each trial,

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one of the circle arrays was filled, the other was outlined. We showed that participants were more accurate when the more variable array was filled [F(1,29)=14.8,p< 0.001]. They also relied more heavily on the range heuristic when texture information was not available [F(1,29)=3.4, p=0.075]. These experiments indicate that range and spatial texture information are both utilized as proxies for variability discrimination, and people are flexible in adopting these strategies whenever they are available. Importantly, these "smart" subsampling strategies are at odds with the claim of parallel processing and random subsampling strategies previously proposed in the literature.

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23.355 **Ensemble representations are robust to noise inherited from the individual item level** Emma ZeeAbrahamsen[1](zeeec-18@rhodes.edu), Jason Haberman[1]; [1]Neuroscience Program in the Department of Psychology, Rhodes College

The visual system efficiently extracts summary statistical information from visual scenes (e.g., sets of oriented gabors, crowds of faces). Ensemble representation precision may in part be driven by the power of statistical averaging, which can be leveraged to overcome noise at the individual item level (Alvarez, 2011). The current experiments explicitly tested this by comparing the representation of noisy individual faces with that of noisy crowds. If the ensemble computation inherited noise from the individual item level in a linearly additive process, we would expect ensemble representations to suffer more with the introduction of noise. However, this was not the case. Observers viewed either individual faces or sets of 4 faces masked in varying degrees of noise (no noise, low, medium, high) and had to adjust a fully visible test face to match the perceived individual or average expression. The difference in precision between the no noise condition and the noise conditions was analyzed in a 3 (noise) x 2 (set size) repeated measures ANOVA. This revealed a main effect of noise, but no effect of set size, indicating that performance did not depend on whether observers assessed a single face or a crowd of faces. The interaction was also not significant. Overall, the results are consistent with the notion that ensemble representations may be more robust to noise than might be expected based on the representation of individual items, a useful outcome given the often noisy inputs available for the ensemble calculus.

23.356 **Representational dynamics of ensemble average of simultaneously presented objects** Kangyong Eo[1](gazz11@empal.com), Oliver James[2], Sangkyu Son[1], Min-Suk Kang[2,3], Sang Chul Chong[4,5], Yee-Joon Kim[1]; [1]Center for Cognition and Sociality, Institute for Basic Science (IBS), Daejeon, Republic of Korea, [2]Center for Basic Neuroscience Imaging Research, Institute for Basic Science (IBS), Suwon, Republic of Korea, [3]Department of Psychology, Sungkyunkwan University, Seoul, Republic of Korea, [4]Graduate Program in Cognitive Science, Yonsei University, Seoul, Republic of Korea, [5]Department of Psychology, Yonsei University, Seoul, Republic of Korea

Ensemble representation is a dimensionality reduction mechanism to deal with information overload by extracting a central tendency from a set of stimuli. Behavioral studies showed that ensemble average of similar stimuli is automatically represented and that the error of ensemble average increases as inter-stimulus variability increases. However, very little is known about neural mechanisms supporting such properties of ensemble representation. Inferred from the recently developed population model of mid-level vision that explains irretrievable loss of information due to the increase in spatial pooling with eccentricity, we hypothesize that ensemble average of a specific feature is a coarse-grained representation wherein high-dimensional neural population activity is projected onto low-dimensional subspace linearly spanned by the basis feature channels. To test this hypothesis, we recorded electroencephalography (EEG) while observers performed a series of tasks related to computing average orientation of an array of 36 randomly oriented Gabor patches with various inter-Gabor orientation variability. We used a forward encoding model to decode neural representation of ensemble average orientation from full EEG signals. We found that the accuracy of recovered ensemble average orientation decreases as inter-Gabor orientation variability increases. Next, we investigated if representational dynamics of ensemble average orientation varies with task demand or not. Initial theta band activity pattern was found to represent ensemble average orientation for 500 ms regardless of whether observers were required of computing ensemble average or not. Furthermore, after transient theta band activity pattern disappeared, alpha band activity pattern was observed to maintain the neural representation of ensemble average orientation for about 800 ms only when observers were required of computing ensemble average. This multiplexed spectral code of ensemble average information may index the variance of neural computations, which translates into the precision of behavioral performance.

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23.357 **Conceptual size ensembles cannot be predicted by individual item size representations** Sneha Suresh[1](sursn-19@rhodes.edu), Jason Haberman[1]; [1]Neuroscience Program in the Department of Psychology, Rhodes College

The visual system compresses redundant information into efficient, ensemble representations by averaging features across items. Ensemble perception operates with remarkable flexibility, even integrating object information at a conceptual level. For example, given a sufficiently strong depth cue, the visual system represents the perceived size of a set of triangles as opposed to their physical size (i.e., it accounts for size constancy; Suresh, Thomasson, & Haberman, VSS, 2017). In the current set of experiments, we explored whether conceptual ensemble size representation may be predicted by the size representation of the individual items composing the group. In every trial, observers viewed an individual triangle with and without linear perspective cues and judged whether a subsequently presented test triangle was larger or smaller than the preceding triangle. Whereas observers were biased to perceive the average size of multiple triangles as larger when presented in the context of linear perspective cues (i.e., conceptual size averaging), they did not take those cues into account when estimating the size of a single triangle. That is, observers perceived a single triangle in the context of linear perspective cues as the same size as a single triangle without linear perspective cues. These results suggest the generation of a conceptual size ensemble cannot be predicted by the individual item representations, which points to an emergent calculus that depends on judgments at the group level.

23.358 **Representation of multiple ensembles across visual domains is more precise than within visual domains** Delaney McDonagh[1](mcddc-19@rhodes.edu), Jason Haberman[1]; [1]Neuroscience Program in the Department of Psychology, Rhodes College

Ensemble perception allows us to rapidly derive summary statistical information from groups of similar objects. Although ensembles are generated quickly and efficiently, the capacity limitations of this process are still debated. The visual system can represent large numbers of items as a single average value, but current research suggests there is a limit to the number of ensembles one can simultaneously extract. We previously demonstrated that the number of ensembles the visual system can effectively represent may depend explicitly on the visual domain (Schill & Haberman, VSS, 2016). In the current study, we replicated and extended those findings. In each trial, observers viewed two ensembles presented simultaneously and were post-cued to report the average of just one of the sets. The ensembles could either be mixed, in which two different visual domains were presented (e.g., faces varying in expression and colored patches varying in hue), or unmixed, in which two sets from the same visual domain were presented. Observers then adjusted a test stimulus to match the preceding set. The results revealed an overall benefit in ensemble representation in mixed conditions relative to unmixed conditions. That is, both average color and average expression representations improved when different ensemble types were present compared to when both sets came from the same visual domain. We conclude that attending to mixed ensembles reduces competition for neural resources, as different ensemble domains rely on independently operating mechanisms.

23.359 **Interactions between statistical set representations and visual stability** Jaap Munneke[1,2,3,](Jaap.Munneke@gmail.com), Jennifer E Corbett[1,2,3]; [1]Aysel Sabuncu Brain Research Center, Bilkent University, Ankara, Turkey, [2]Dept. of Psychology, Bilkent University, Ankara , Turkey, [3]Interdisciplinary Neuroscience Graduate Program, Bilkent University, Ankara , Turkey

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Despite continuous retinal chaos, we perceive the world as stable and complete. This illusion of stability is evoked over consecutive glances via redundancies in higher-order statistical information inherent in the visual environment. For instance, prior work has shown that repeating the average size of a set of differently sized circles over consecutive trials yielded faster reaction times in complex search tasks, compared to similar trials in which mean size was not repeated. In the current work, we elaborate on these findings, proposing that the main effect of visual stability on search times is attentional in nature. Observers conducted a difficult conjunction search task in which a tilted Gabor with a pre-defined spatial frequency had to be detected among a number of elements. Crucially, the mean size of the set of Gabors could either be kept constant over a series of trials, or changed on each trial. Importantly, regardless of the build-up of stability, individual elements changed on every trial. To investigate the involvement of attention, the number of elements (set size) could vary from trial-to-trial. Results show that search is strongly facilitated by visual stability, with faster response times for stable trials compared to unstable trials, such that 1) The effect of stability is independent of, and transfers over displays with different set sizes, 2) Faster response times benefit more from stability compared to slow response times, 3) A minimum number of repetitions is required to find a robust stability effect. Results of these experiments are discussed in terms of attentional capacity and change detection mechanisms.

23.360 **The end of motion: How the structure of simple visual events impacts working memory and enumeration** Joan Danielle K Ongchoco[1](joan.ongchoco@gmail.com), Brian Scholl[1]; [1]Department of Psychology, Yale University

Beyond static scenes, our visual experience is populated by dynamic visual events — and these frequently overlap in time, as events are continuously and asynchronously starting, unfolding, and ending all around us. How do we represent and remember events amidst this rush of things that are always happening? The mind could simply accumulate information largely regardless of how that information is bound into particular discrete events. Or information could be prioritized when it marks the onset of a new event. Or information may only be stored for as long as its 'parent' event is ongoing (as in models that posit 'memory flushing' at event boundaries). We explored such possibilities using maximally simple visual events. Observers viewed animations with a number of initially-static dots. A subset of dots then moved in random directions and speeds, and eventually (e.g. after 1s) were again static — but in some conditions these motions could occur asynchronously, with each dot potentially beginning and ending its motion at a different moment. On each trial, observers simply had to estimate the number of dots that had moved. An animation's event structure — i.e. just when the motions started and stopped — had a strong impact on performance: asynchronous motions were consistently underestimated relative to synchronous motions. Further comparisons revealed that the (a)synchrony of motion onsets had little effect, whereas asynchrony of motion offsets always led to underestimation (regardless of whether onsets were simultaneously synchronous or not). Thus, when attempting to answer questions of "how many moved?", the visual system seems to instead deliver information about "how many just stopped moving?". In other words, the ends of events seem to have an outsize influence on working memory: once a motion ends, it seems more difficult to recall that particular motion as having occurred as a distinct event.

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23.361 **Dissociating Parallel and Serial Processing of Numerical Value** Kassandra R Lee[1](kassandra_lee@meei.harvard.edu), Kenith V. Sobel[2], A. Kane York[2], Amrita M. Puri[3]; [1]Schepens Eye Research Institute, Harvard Medical School, [2]Department of Psychology and Counseling, University of Central Arkansas, [3]Department of Biology, University of Central Arkansas

Ensemble coding is a visual processing mechanism that allows for the rapid extraction of statistical summary information from groups of stimuli. It has been shown that ensemble coding operates for low-level visual features such as line orientation (e.g, Dakin & Watt, 1997; Parkes, Lund, Angelucci, Solomon, & Morgan, 2001), as well as higher-level attributes such as facial emotion (e.g, Haberman & Whitney, 2007). Recent work suggests that semantic information is extracted automatically from arrays of digits and influences summary representations of subsequent digit displays (Van Opstal, de Lange, & Dehaene, 2011). Here, we investigated whether numerical information can be extracted in parallel across digits within a display. Participants reported the average (< 5, >5) of digit ensembles with varying numbers of items within the displays. We compared reaction time (RT) patterns across increasing display sizes for the averaging task to RTs from the same participants on visual search tasks using identical displays as in the averaging task, but designed to yield RT slope characteristics of serial (search for a digit < 5 or >5; target is the same color as distractors) and parallel (search for a digit < 5 or >5; target is always red) processing. In a second experiment we controlled for brightness, a low-level cue that could have contributed to performance in experiment 1. Across experiments, search tasks yielded RT slopes typical of serial and parallel search tasks. Unlike in either search task, however, RTs for the ensemble (averaging) tasks decreased with increasing display size. These results indicate that semantic information from multiple digits may be extracted by a parallel processing mechanism. Furthermore, decreasing RTs with increasing display size may reflect a potential benefit of larger displays, as has been previously reported for ensemble perception (Sweeny & Whitney, 2014).

23.362 **Confusing the Trees for the Forest: Number Estimation in Real-World Scenes** Darko Odic[1](darko.odic@psych.ubc.ca); [1]University of British Columbia

When observing a simple visual scene, such as an array of dots, observers can easily and automatically extract their number. How does the visual system accomplish this feat? We tested the degree to which number perception relies on real-world experience by testing how well participants estimate the number of objects embedded within real scenes, such as those in Figure 1 (e.g., "How many chairs are on this beach?"). In Experiment 1 (N = 25), participants estimated either the number of black dots on a white background or the number of objects shown within a mix of indoor and outdoor scenes (Figure 1). Surprisingly, we found that participants were severely impaired at estimating the number of objects in real-world scenes, showing four times the estimation error compared to the dot stimuli. In Experiment 2 (N = 48), we investigated whether this impairment is simply caused by the irrelevant background information drawing attention away from the objects. Participants estimated the number of objects in scenes whose background was either faded to grayscale or entirely removed, thereby allowing participants to easily locate the objects (Figure 1). Although participants performed marginally better when the background was entirely eliminated, we still found that number perception is severely impaired in scenes compared to dot stimuli in either condition. Finally, in Experiment 3 (N = 50), we found that participants showed no impairment when estimating the number of objects that were randomly positioned on the screen, suggesting that the impairment in Experiments 1 and 2 stems entirely from the actual distribution of objects in the real-world scenes, not from the identity of the objects themselves. In conclusion, we find that – despite having decades of experience in scene perception - observers are surprisingly poor at estimating the number of objects embedded within real world scenes.

23.363 **Dynamics of numerosity representation in early visual cortex.** Michele Fornaciai[1](mfornaciai@umass.edu), Joonkoo Park[1,2]; [1]Department of Psychological and Brain Sciences, University of Massachusetts, Amherst, MA, USA., [2]Commonwealth Honors College, University of Massachusetts, Amherst, MA, USA.

While the representation of numerical magnitude is thought to reside in the parietal cortex, recent studies have started to reveal the role of early visual cortex in numerical magnitude processing. Here, we provide novel evidence for the critical involvement of early visual regions in numerosity perception. By using the connectedness illusion, whereby arrays with pairwise connected dots are perceived to be less numerous compared to arrays containing isolated dots, we dissociated veridical (i.e. the actual number of dots) and perceived (i.e. numerosity reduced by connectedness) numerosity. Exploiting this illusion, we trace the temporal (using EEG) and anatomical (using fMRI) evolution of numerosity representation from veridical to perceived representations in the cortical visual pathways. The results show that while visual area V2 mainly respond to the veridical numerical magnitude of the stimuli, activity in area V3 reflects both veridical and perceived numerosity, at different latencies. Namely, V3 encodes veridical numerosity earlier in the processing stream (100ms), while it encodes perceived numerosity at a later time point (150ms). These findings highlight the neural dynamics in early visual areas underpinning numerosity perception and indicate that area V3 represents a crucial node mediating the transformation of sensory information into subjective experience.

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23.364 **A distributed attention model of mean size perception** Sang Chul Chong[1,2](scchong@yonsei.ac.kr), Jongsoo Baek[3]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University, [3]Yonsei Institute of Convergence Technology, Yonsei University

When viewing a scene, people have to summarize redundant information in a complex scene to overcome the limited capacity of the visual system. One way of summarizing information is perceptual averaging. The ability to compute average information is accurate and efficient across many stages of visual processing. However, the exact mechanism of averaging is not well understood. Here, we propose a distributed attention model of mean size perception. The model encodes and represents sizes with both early and late noise to reflect noisy percepts. It incorporates the central limit theorem to reflect noise cancellation by averaging. Finally, it has a component of attention to modulate the amount of attention allocated to each to-be-averaged item. The model predicts that averaging performance should increase as the number of to-be-averaged items increases, because of the central limit theorem. The slope of these increments should decelerate, especially for large set-sizes, because of late noise. Finally, the effects of attention should be manifested more in small set-sizes because of the limited capacity of attention. We tested these predictions using a mean size discrimination task. Critically, we varied the number of to-be-averaged items from 1 to 32. The model explained the observed data almost perfectly ($r2 = .99$) and the results were consistent with the model's predictions qualitatively. Observers' precision of averaging significantly increased with set-sizes. Increments in precision were prominent in small set-sizes and decelerated in large set-sizes. Attention parameters, assuming equal weights on all items (distributed attention), explained the increased precision of averaging in small set-sizes. Late noise parameters explained the decelerated precision of averaging in large set-sizes. Furthermore, the model explains why some previous studies, but not others, found set-size effects on averaging. The model provides a theoretical framework to interpret behavioral data and allows us to understand the characteristics of ensemble perception.

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23.366 **Emotional judgments of individual scenes are influenced by unintentional averaging** Yavin Alwis[1](alwyv-20@rhodes.edu), Jason Haberman[1]; [1]Neuroscience Program in the Department of Psychology, Rhodes College

The visual system uses ensemble perception to summarize visual input across a variety of domains. This heuristic operates at the highest levels of vision, compressing information as complex as emotion, animacy, and scene valence into an efficient representation. Previous work has shown the average size of a set can influence the perceived size of an individual item, and vice versa (Brady & Alvarez, 2011), but it has yet to be demonstrated whether such effects emerge for high-level stimuli, specifically, emotional scenes. In the current experiment, we tested whether the perceived emotional valence of a single scene could be influenced by surrounding, simultaneously presented scenes. Observers first rated the emotional valence of a series of individual scenes. Observers then saw ensembles of the original images and were cued to rerate just one of the four. We predicted the perceived emotional valence of the cued image would be pulled toward the mean emotion of the surrounding ensemble. Results confirmed this. The correlations across observers revealed that the bigger the difference between the valence of the ensemble and the valence of the cued image, the more the rating of the cued image shifted toward the average of the ensemble. We conclude that high-level ensemble information can influence how we perceive individual items in the crowd, even when that information is not directly task relevant.

23.367 **Gestalt grouping facilitates perceptual averaging to boost memory efficiency** Jennifer E Corbett[1,2,3](jennifer.e.corbett@gmail.com), Ceren Okatan[1], Jaap Munneke[1,2,3]; [1]Bilkent University Aysel Sabuncu Brain Research Center, [2]Bilkent University Department of Psychology , [3]Bilkent University Interdisciplinary Neuroscience Graduate Program

Visual short-term memory (VSTM) is limited to representing only about four items in detail, yet we have the perception of seeing the world around us in full resolution from moment-to-moment. One way the limited capacity visual system might accomplish this illusion of stable and complete perception is by relying on higher-order statistics inherent in the surrounding environment to parsimoniously organize and represent information. Given recent reports that the visual system represents average properties of Gestalt-grouped sets of individual objects, we hypothesized that grouping and averaging may enhance memory capacity (as indexed by the amplitude of the contralateral delay activity (CDA)) beyond the traditional four-item limit. We presented observers with study displays of four or 16 differently-sized circles, and then asked them to adjust two subsequently-presented test circles to match the remembered sizes of the two corresponding circles in the study display. The circles in the study display could be ungrouped, or grouped into two sets, one with a large mean size and one with a small mean size, according to the Gestalt principles of Similarity, Proximity, Connectedness, or Common Region. Unbeknownst to participants, the two test circles were always the same physical size. However, when the test circle was a member of the previously presented Gestalt-defined set with the large mean size, they adjusted it larger than when it was a member of the small mean size set. Furthermore, CDA amplitude decreased in the grouped compared to ungrouped conditions when there were 16, but not four items in the study displays. Taken together, these results imply that Gestalt grouping boosts memory capacity beyond the traditional four-item limit by biasing the memory for individual items toward the mean of the Gestalt-defined group.

Multisensory Processing: Vision, haptics, body image

Saturday, May 19, 8:30 am - 12:30 pm, Banyan Breezeway

23.368 **Teaching visual orientation discrimination through tactile learning** Dingzhi Hu[1](dianahu@pku.edu.cn), Guozhen Liu[1], Lihan Chen[1], Cong Yu[1]; [1]Psychology, McGovern Brain Research, & Center for Life Sciences, Peking University

Our previous double training studies demonstrate that perceptual learning can generalize to not only new locations and orientations (Xiao_et_al., 2008; Zhang_et_al., 2010), but also new physical stimuli encoded by different neural substrates (Wang_et_al., 2016). These results suggest that perceptual learning involves learning of sensory concepts (e.g., an orientation concept). Here we further show that such a concept can be represented and improved across sensory modalities. The participants first practiced tactile orientation discrimination of a 3D-printed grating at 40o or 130o with index fingers. Although training improved tactile orientation thresholds (35.2%, $p=0.029$), it didn't affect visual orientation discrimination at the trained orientation ($p=0.15$) and an orthogonal orientation ($p=0.09$). The participants then practiced an irrelevant visual contrast discrimination task at the trained orientation. After that, visual orientation discrimination was improved at both trained (33.4%, $p< 0.001$) and untrained orientations (22.9%, $p=0.011$). Further training of visual orientation discrimination failed to produce additional gain (-7.3%). In a second experiment, tactile orientation and visual contrast tasks were trained in the same sessions in alternating blocks of trials, which improved visual orientation discrimination at both trained (39.8%, $p< 0.001$) and untrained orientations (27.5%, $p=0.004$). Further training of visual orientation did not improve visual orientation thresholds (1.6%, $p=0.80$). These results indicate that tactile orientation learning can transfer completely to visual orientation with double training. In addition, we found that tactile orientation learning can transfer to an orthogonal tactile orientation with double training. These results provide further support for our claim that

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perceptual learning is concept learning (Wang_et_al., 2016), and suggest that stimulus orientation as a concept can be represented and improved through training at a modality-independent level. Learning transfers to a new sensory modality after the learned concept functionally connects to sensory inputs from the new modality through double training.

Acknowledgement: NSF of China

23.369 **Multisensory Detection: Using Vision and Haptics to detect hidden objects.** Julie B Skevik[1], Peter Scarfe[1]; [1]Vision and Haptics Laboratory, School of Psychology and Clinical Language Sciences, University of Reading

Data from several studies show that when information is available from both vision and haptics simultaneously, people have a higher level of precision in discriminating properties such as size and shape, compared to either cue in isolation (Ernst and Banks 2002; Helbig and Ernst 2007). Most studies on the topic of visuo-haptic cue combination have focussed on discrimination, while few studies have investigated the effects on detection. In this experiment, we investigated whether these benefits would hold true in detection tasks, which have more relevance to applied situations such as the detection and delineation of cancerous tumours in medical imaging data (Abbey and Eckstein 2009). Participants had to compare two image patches presented on a computer monitor in a two-alternative forced choice task and detect which of the two patches contained a hidden 2D Gaussian profile. Information was available from touch, vision or both touch and vision simultaneously. Haptic feedback was provided by a desktop Phantom force feedback device and visual reliability parametrically manipulated by adding Gaussian white noise to each patch. Haptic stimuli maintained a constant level of reliability across conditions. Our findings are in line with those of previous discrimination studies. Observers are consistently better at detecting the hidden Gaussian signal across visual noise levels when both visual and haptic information were available, compared to either modality in isolation. We discuss our results in relation to models of optimal sensory cue combination, applied tasks such as tumour delineation and examine the haptic predictors of good performance.

Acknowledgement: EPSRC

23.370 **The Sequential-Weight Illusion** Guido Maiello[1](guido_maiello@yahoo.it), Vivian C Paulun[1], Lina K Klein[1], Roland W Fleming[1]; [1]Department of Experimental Psychology, University of Gießen, Germany

We report a perceptual illusion in which the perceived weight of an object appears to change depending on whether a previously manipulated object was lighter or heavier. Two equally sized objects (12.5×2.5×2.5cm), a light wooden object (50g) and a heavy object made of brass (670g), were placed in front of a participant. The participant briefly picked up the wooden object and placed it back down. The participant then picked up the brass object and placed it back down. Finally, the participant picked up the wooden object once more. Strikingly, the wooden object appeared to have lost a substantial amount of weight (-37% median change in weight rating, N=25, p= 0.000010). The illusion worked for the opposite sequence of weight ordering as well: a heavy object appeared to become approximately 11% heavier after picking up a light object (N=10, p=0.010). The illusion is likely related to the interaction between short term motor adaptation and the violation of sensorimotor expectations [Polanen and Davare, 2015]. The forces applied at the fingertips when grasping an object are biased towards those required to grasp the previous object. When fingertip forces do not match the current object weight, online motor corrections rescale both force control and weight estimation. Because our brain must integrate visual and sensorimotor representations to plan our movements, we asked whether visual cues to weight play a role in this illusion. We had participants rate the perceived weight of the alternating heavy and light objects with only sensorimotor or both visual and sensorimotor cues to weight. The strength of the illusion was not modulated by the presence/absence of visual cues (N=35, p=0.55). Thus, our findings demonstrate that visual cues are not integrated with sensorimotor cues during online updating of perceived object weight.

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23.371 **Quantifying the contribution of visual and haptic feedback to the size-weight illusion: a meta-analytic review** Elizabeth J Saccone[1](e.saccone@latrobe.edu.au), Oriane Landry[1], Philippe A Chouinard[1]; [1]School of Psychological and Public Health, La Trobe University, Bendigo, Australia

Weight illusions demonstrate that an object's physical properties influence our subjective experience of its heaviness. The most robust illusion is the size-weight illusion (SWI), in which the smaller of two objects of equal mass feels heavier. Although several theories exist to explain the illusion, none account for all relevant findings. One set of theories attributes the SWI to bottom-up processes, proposing that certain object-related variables are directly perceived by the body during lifting, variables that must be interpreted consciously as heaviness. These theories include a critical role of haptic/somatosensory feedback of size in the illusion; however, there is mixed evidence regarding the contribution of haptic compared to visual input. We conducted a meta-analytic review of the SWI literature to quantify the contribution of visual and haptic information to illusion strength. Following literature searches and email communication with authors, we obtained data comprising perceptual heaviness estimates for stimuli with the same mass but different volumes. Data were included from 27 studies, including 4 unpublished datasets. Mean perceptual estimates were compared for stimulus pairs (e.g., smaller vs larger) within each study/experiment, and used to calculate effect size observations (d), weighted by sample size. Results demonstrated the SWI was comparable across the following conditions: with visual feedback, without haptic feedback (n=21; mean weighted d = 2.09, 95% CI 1.90-2.28), with haptic feedback, without vision (n=30, mean weighted d = 2.19, 95% CI 2.07-2.32) with both visual and haptic feedback (n=106, mean weighted d = 1.95, 95% CI 1.89-2.01). Findings suggest that both visual and haptic information elicit a SWI of comparable strength, with no additive effect of the modalities. The results do not support theories proposing a critical role of haptic/somatosensory information in the SWI, thus pointing to an alternative mechanism. Publication bias remains an issue and will be investigated in future analyses.

23.372 **Vision and touch are not automatically integrated** Stephanie Badde[1,2](stephanie.badde@nyu.edu), Karen T Navarro[3], Michael S Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of Psychology, City College of New York

Vision and touch code spatial information in different reference frames. For sensory integration, establishing whether visual and tactile stimuli share a common source is costly and might not occur automatically. We tested whether task-enforced encoding of both visual and tactile stimulus locations fosters multisensory integration (Experiment 1) and cross-sensory calibration (Experiment 2). On each trial, a visual, tactile or visual-tactile stimulus was presented on a participant's occluded arm. Participants indicated the location of one stimulus. In multisensory trials, a cue indicated which modality to localize. This cue was pre- or post-stimulation (varied across participants); the latter forces participants to encode both vision and touch. Experiment 1: Unisensory and multisensory trials were interleaved, and visual-tactile pairs with different spatial discrepancies were tested. After localizing the cued stimulus, participants indicated whether they perceived the stimuli in the same (fusion) or in different (non-fusion) locations. Experiment 2: Unisensory and multisensory trials were blocked, and visual-tactile stimulus pairs with one fixed spatial discrepancy were presented in multisensory trials. Unisensory localization performance was tested before and after the multisensory phase. In Experiment 1, tactile location reports were shifted towards the location of the visual stimulus, indicating multisensory integration. Crucially, when the relevant modality was cued after — rather than before — the stimuli, tactile localization was also shifted in non-fusion trials, and the proportion of fused percepts increased. In Experiment 2, when the relevant modality was cued after the stimuli in multisensory trials, tactile localization in subsequent unisensory trials was significantly shifted, indicating cross-sensory calibration. This was not the case when the cue occurred before the stimuli. In sum, we found stronger effects of vision on touch when post-stimulation cueing forced participants to encode spatial information from both modalities. Hence, integration of visual and tactile spatial information is not an automatic process.

23.373 **Feeling a flash** Michael Landy[1,2](landy@nyu.edu), Stephanie Badde[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Often, vision provides a more precise location estimate than touch. Consequently, the perceived location of a tactile stimulus is pulled entirely towards the location of a spatially discrepant, synchronously presented, visual stimulus. However, this is only true if the visual and tactile stimuli are perceived as coming from the same source. When perceived from different sources, the perceived tactile location should be unbiased. This leads to a tactile posterior distribution peaking at two separated locations when the same-source judgment is ambiguous. Here, we investigated an observation that participants sometimes report two tactile stimuli in such situations. Participants placed their non-dominant arm parallel to their torso on a tabletop. Tactile stimulators and LEDs were attached to the participant's lower arm (three locations, separated by 3 cm). The arm was occluded from vision by a translucent cover. In each trial, participants received either one or two tactile stimuli with equal probability. In half of the trials, one LED was flashed at the same time as the tactile stimulation. This flash occurred randomly at any one of the three locations. At this range of distances between flash and touch, same-source judgments are ambiguous. Participants reported whether they perceived one or two tactile stimuli, ignoring any visual stimulation. The probability of reporting two tactile stimuli was higher in bimodal trials. Crucially, the probability of erroneously reporting a second illusory tactile stimulus increased with the distance between flash and touch. The probability of correctly reporting two tactile stimuli was higher when the two tactile stimuli had greater spatial separation. A flash increased the probability of correctly reporting two tactile stimuli, especially if the flash was presented at the same location as one of the tactile stimuli. The brain resolves ambiguous spatial information for two tactile locations by perceiving an additional illusory touch.

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23.374 **Crossmodal correspondence between haptic shape and sound** Yuna Kwak[1](eunice0909@korea.ac.kr), Ho-Sung Nam[2], Chai-Youn Kim[1]; [1]Department of Psychology, Korea University, [2]Department of English Language and Literature, Korea University

Accumulating evidence has demonstrated the existence of non-arbitrary correspondence between sensory modalities. For example, studies report non-arbitrary relationship between visual shape and sound: people tend to label a round shape 'bouba' and a spiky shape 'kiki' (Köhler, 1947; Ramachandran & Hubbard, 2001). Since such relationship is well established mostly in the visual and auditory domain, the present study aimed to examine the correspondence between the haptic and auditory modality, which has not been illuminated much in previous studies. A three-dimensional, round and a spiky haptic stimulus were generated with a parametric shape model (Lee Masson et al., 2016), and linear interpolation was carried out on the coordinates of the two stimuli to generate five more stimuli in between. As a result, there were total seven haptic stimuli, of which the roundness/spikiness dimension was equi-distantly manipulated. Multidimensional scaling analysis confirmed that physical spaces conformed to perceptual space, showing the effectiveness of the manipulation of the physical parameters. For the auditory stimuli, we used Haskins Articulatory Synthesizer to generate two vowel sounds by manipulating the height and frontness of the tongue body position (e.g. /a/, /i/). These sounds were shown to be associated with either round or spiky visual shape (Kwak et al., iMRF 2017). On each trial of the experiment, participants (N=19) had to palpate a haptic stimulus for 5 seconds, after which it was taken away by the experimenter. Then the two sounds were presented sequentially, and the participants had to choose the sound that better matched the object. Results showed the main effect of shape: the roundest object was associated with /a/, whereas the spikiest object was associated with /i/, and responses for the objects in between were modulated according to the roundness/spikiness dimension. These results suggest that the correspondence between shape and sound extends to haptics and audition.

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23.375 **Consistency of Individual Measurements Between Different Sensory Modalities: Vision vs. Audition and the Haptic Senses** Russell Adams[1,2](michelem@mun.ca), Michele Mercer[1], Jagger Mercer/Adams[1]; [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. In recent work (VSS 2013, 2015), we have made comparisons among the human senses, focusing primarily on common patterns within general threshold responding. Results show that vision (notably contrast sensitivity) shares some commonalities with audition and surprisingly, and also with some aspects within the sense of pain. Another question, particularly for clinicians, is which of these modalities yields the most consistent results across assessments. To address this question, we conducted an intensive assessment of adults tested repeatedly with primarily psychophysical measures of vision, hearing, touch and pain. Method. 15 young adults were tested repeatedly (M = 8 repetitions) with the most widely used clinical measures of spatial vision [log MAR optotype acuity, contrast sensitivity (FACT, Vector Vision, Rabin tests), and refractive error (autorefraction)], audition (complete audiology exam), touch (Von Frey fibres on the ventral and dorsal aspects of the hand), and pain (fingertip pressure algometry). Results. To make measures comparable, data across all tests and modalities were standardized to individual logarithmic scales. Coefficient of reliability analyses showed that except for autorefraction, all measures of vision showed the most consistency, followed by measures of touch, audition, and pain. Conclusions. Our data indicate that, except for optical measurements (likely due to varying accommodation), repeated assessments of vision (often weeks apart) are highly stable, and are superior in this regard to the other sensory modalities. Although this may be due in part to the precision and scaling of the existing psychophysical techniques for measuring vision, it also may be due to the fact that threshold decision making within visual tasks requires the highest degree of cortical integration among all sensory modalities.

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23.376 **Sensorimotor finger-specific information in the cortex of the congenitally blind** Daan B Wesselink[1,2](daan.wesselink@ndcn.ox.ac.uk), Sanne Kikkert[2,3], Holly Bridge[2], Tamar R Makin[1,2]; [1]Institute of Cognitive Neuroscience, University College London, [2]FMRIB Centre, University of Oxford, [3]Donders Institute for Brain, Cognition and Behaviour

Regions of the occipital and temporal cortices, used for vision in sighted people, are activated by touch in the congenital absence of vision. It is unclear whether such occipitotemporal activity reflects low-level sensorimotor or higher-order amodal processing. To test this, we probed hand representation using ultra high-field (7T) fMRI in four individuals with bilateral congenital anophthalmia (a condition in which the eyes fail to develop) and eight blindfolded sighted control participants. All participants performed an active tapping task with each finger of the right hand (1 mm3 resolution, limited field of view capturing the supplementary motor area (SMA), primary somatosensory cortex (S1) and the lateral occipitotemporal cortex (LOTC). To determine whether a certain area displayed canonical low-level sensorimotor organisation we compared finger individuation in that area, as measured using multivariate pattern analysis (MVPA). Additionally, we compared inter-finger overlap in representation patterns to the pattern observed in finger-selective SI. In line with previous reports, 3/4 anophthalmic but no sighted participants showed bilateral activation in the LOTC during finger movements (70% of SI's levels). While the analysis did not reveal S1-like organization in LOTC in either group, the activity patterns induced by individual fingers could be separated: A cross-validated multivariate classifier (neural network; 1 hidden layer of 10 nodes; trained on 7 out of 8 runs) showed significant above-chance performance on finger classification in LOTC (5/6 hemispheres, 27% on average versus 20% chance). By comparison, the same analysis performed 38% in SMA and 88% in SI. None of the sighted participants showed above-chance finger classification in LOTC. To conclude, LOTC is strongly activated during simple hand movements in congenitally blind individuals. While not organised canonically, this activity contains information about individual fingers, suggesting the presence of low-level sensorimotor processes in the blind, not found in the sighted brain.

23.377 **Where am I? In terms of my physical and of my perceived body** Albert H van der Veer[1,2](albert.h.vanderveer@hotmail.com), Matthew R Longo[3], Adrian JT Alsmith[4], Hong Yu Wong[5,6], Heinrich H Bülthoff[1], Betty J Mohler[1,7,8]; [1]Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [2]Graduate Training Centre of Neuroscience, University of Tübingen, Germany, [3]Department of Psychological Sciences, Birkbeck, University of London, United Kingdom, [4]Center for Subjectivity Research, University of Copenhagen, Denmark, [5]Philosophisches Seminar, University of Tübingen, Germany , [6]Werner Reichardt Centre for Integrative Neuroscience, University of Tübingen, Germany, [7]Max Planck Institute for Intelligent Systems, Tübingen, Germany, [8]Institute for Sport Science, Technical University Darmstadt, Germany

We investigated the following three questions: 1) Where do people locate themselves on their body? 2) How precisely can people locate their body parts? and 3) Do people locate themselves differently in terms of their perceived compared to their physical body dimensions? Alsmith and Longo (2014) asked participants to point directly to themselves with a physical pointer. They found pointing to be to two distinct locations, upper face and upper torso. To investigate the robustness of their findings, we used virtual reality (VR), because this allows for systematic control over experimental variables and easy manipulation of visual information. In a VR headset and on a large-scale immersive display, participants rotated a pointer in their sagittal plane instructed to “Point directly to you”, but also to nine of their body parts (feet, knees, hips, waist, shoulders, chin, nose, eyes and top of the head) previously measured for their physical heights. From the pointed-to body parts a perceived body was constructed, to which the self-locations were alternatively scaled/normalized. Pointing to self relative to the physical body was frequently found for all body regions above mid-torso, as well as above the head (Supplement, left graph). Participants pointed precisely to many body parts, but not to feet and knees, nor to the top of the head. Relative to the perceived body, pointing to self resembled more the results from the earlier physical setup, that is participants pointed mainly to upper torso and the face (Supplement, right graph). These results suggest, that a) people do not have one specific location where they locate themselves, and b) people do not accurately point to their entire body in the vertical plane. Alsmith, A. J. T. & Longo, M. R. (2014). Where exactly am I? Self-location judgements distribute between head and torso. Consciousness and Cognition, 24, 70-74.

Acknowledgement: Volkswagen Foundation

23.378 **Distortions of Body Image in Healthy Adults: A Meta-Analysis** Matthew R Longo[1](m.longo@bbk.ac.uk); [1]Department of Psychological Sciences, Birkbeck, University of London

Distortions of the experienced size and shape of the body (i.e., the body image) are a conspicuous feature of several serious clinical disorders, including anorexia nervosa and body dysmorphic disorder. A large literature has used body size estimation methods to compare body image in patients and healthy controls. A general finding, supported by several previous meta-analyses, is that patients with eating disorders overestimate body width relative to controls. Here, I investigated performance on these tasks in healthy adults, focusing on the control groups from studies investigating patients and on studies of non-clinical samples. A total of 632 studies were identified using body-size estimation methods. From these, non-clinical adult samples were selected, excluding samples designated as having any clinical disorder, such as an eating disorder, obesity, or schizophrenia. Overestimation of body width was calculated for two types of tasks: depictive tasks in which the participant compares their body to a visual image of a body (e.g., the distorted picture or video distortion tasks), and metric tasks in which the participant compares the perceived size of part of their body to a metric standard (e.g., the moving caliper and image marking tasks). In both cases, I focused on judgments in the frontal body plane. For each task, random-effects meta-analysis was used to estimate the mean percentage overestimation of body width and its 95% confidence interval. Despite considerable between-study variability, depictive tasks showed no evidence for systematic deviation from veridical judgments (see Supplemental Figure). In contrast, metric methods showed systematic overestimation of body width, ranging from 10-20% across tasks. Importantly, judgments of non-body objects showed no such distortions, indicating that the overestimations of body width are not an artefact of task demands. These results show that distortions in body image are not exclusive to disease, but are a normal part of healthy cognition.

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23.379 **No change in perceived hand size after Rubber Hand Illusion induction** Sam Thomasson[1](thosw-18@rhodes.edu), Jason Haberman[1]; [1]Neuroscience Program in the Department of Psychology at Rhodes College

The human brain develops a representation of one’s own body by integrating visual, proprioceptive, and somatosensory information into a coherent whole. This representation can be altered or disrupted when the sensory input is altered. Notably, the Rubber Hand Illusion (RHI) can be used to induce ownership of a fake hand into a subject’s self-representation. In one study with upper arm amputees, by stroking amputees’ stumps while synchronously stroking a visible fake hand, the illusion caused the stroke to be felt in the location of the fake hand (Ehrsson et al. 2008). Although the RHI may be robustly induced by objects that only vaguely resemble a real hand (e.g., a rubber glove), it remains unknown whether the size representation of one’s hand may be manipulated by changing the size of the inducer. In the current set of experiments, we tested whether induction of the Rubber Hand Illusion can consistently alter an observer’s hand size representation toward the size of the fake hand. In a 2AFC task, observers were shown images of their own hand at various sizes and asked to respond as to whether the image was smaller or larger than their real hand, before and after induction of the Rubber Hand Illusion. After successful induction of the illusion, observers’ responses did not show a change in perceived size of their own hand. This implies that while observers may experience ownership of the hand, they are not integrating all features of the hand (e.g., size) into their own body representations.

Visual Memory: Neural correlates

Saturday, May 19, 8:30 am - 12:30 pm, Pavilion

23.401 **A Frontotemporal Regional Model of Post-Traumatic Stress Disorder** Catherine A Mikkelsen[1,2](cmikkels@bu.edu), Arash Yazdanbakhsh[1,2,3,4]; [1]Graduate Program for Neuroscience, Boston University, Boston, MA 02215, [2]Center for Systems Neuroscience, Boston University, Boston, MA 02215, [3]Psychological and Brain Sciences, Boston University, Boston, MA 02215, [4]Center for Research in Sensory Communications and Neural Technology (CReSCNT), Boston University, Boston, MA 02215

The flashback is a phenomenon in Post-Traumatic Stress Disorder (PTSD) in which traumatic memories are replayed as a reaction to a stimulus. However, the underlying neural mechanisms for this phenomenon are still under investigation. We created a multi-layer model of visual input, entorhinal cortex, hippocampus, prefrontal cortex, basolateral amygdala, and the central nucleus of the amygdala, as a multi-area network to determine how these regions may be distinctively encoding the traumatic events that produce these replays. The current model dynamic shows that highly emotional visual stimuli can be generalized to similar stimuli, more so than events related to neutral stimuli. This result mimics electrophysiological results in the amygdala (Ghosh & Chattarji, 2015). Our network dynamics can be used to create a more nuanced approach to PTSD treatments: it could replicate outcomes of techniques such as Prolonged Exposure (PE) and Eye Movement Desensitization and Reprocessing (EMDR) and improve the spatial and temporal configuration of the technique. Our model characterizes the spatio-temporal aspects of the flashback phenomenon and as such aids in the spatio-temporal fine-tuning of treatments such as EMDR. As a future direction, we can incorporate in the model individual and developmental differences in plasticity in responding to current treatments based on visual stimuli to come up with optimized treatment for each individual affected by PTSD.

23.402 **Integrated Cognitive Assessment: Speed and Accuracy of Visual Processing as a Proxy to Cognitive Performance**
Seyed-Mahdi Khaligh-Razavi[1,2](s.mahdirazavi@gmail.com), Sina Habibi[3], Elham Sadeghi[4], Chris Kalafatis[5]; [1]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology, Cambridge, Massachusetts, USA., [2]Department of Brain and Cognitive Sciences, Cell Science Research Center, Royan Institute for Stem Cell Biology and Technology, ACECR, Tehran, Iran, [3]Cognetivity ltd, London, UK, [4]Tehran University of Medical Sciences, Tehran, Iran, [5]South London & Maudsley NHS Foundation Trust, London, UK

Various mental disorders are accompanied by some level of cognitive impairment. In particular, in neurodegenerative disorders, such as Alzheimer's disease, cognitive impairment is the phenotypical hallmark of the disease. Effective, accurate and timely cognitive assessment is key to diagnosis of this family of mental disorders. Currently available techniques for cognitive assessment are primarily paper-based, and need to be administered by a healthcare professional; they are additionally language and education-dependent and can be learnt after taking the test for few times. These tests are thus not ideal for large-scale pro-active cognitive screening and cognitive monitoring. We developed a 5-minute computerized cognitive assessment tool based on a rapid visual categorization task (animal vs. non-animal), in which a series of carefully selected natural images of varied difficulty were presented to participants. 221 participants took part in the experiment (108 female); participant's age range varied from 46 to 98 (mean=74;SD=10). In addition to this computerized test, subjects took the Montreal Cognitive Assessment (MoCA), which is a widely-used pen and paper cognitive test. A linear combination of subjects' speed of visuomotor processing (as measured by their reaction time) and their categorization accuracy was significantly correlated with their cognitive performance (as measured by MoCA; Spearman's R=0.47,p< 0.0000001;two-sided permutation test). This correlation is within the acceptable range for determining construct validity for psychometric tests. Interestingly, while subjects' MoCA score was correlated with their level of education (R=0.38,p< 0.0001), their computerized cognitive score was not (R=0.02,not-significant), suggesting that the proposed computerized test can assess cognitive performance independent of education. In sum, we showed that the combination of speed and accuracy of visual processing in a rapid visual categorization task is a good proxy to cognitive performance. Additionally, the proposed test, while showed to be independent of education, is intrinsically independent of language and culture, and is self-administered.

23.403 **Perceptually-matched images that are meaningful are remembered better and result in increased CDA in visual working memory**
Isabel Asp[1](isabel.e.asp@gmail.com), Viola S Störmer[1], Timothy F Brady[1]; [1]Psychology, University of California, San Diego

People are able to hold more items in visual working memory (VWM) when asked to remember meaningful stimuli (e.g., umbrella) than abstract stimuli (e.g., blue square) (e.g., Brady et al. 2016). However, in previous work, real-world objects and abstract stimuli were not controlled for perceptual equivalency. It is therefore possible that differences in VWM capacity were driven by perceptual properties (e.g., visual information load) rather than representational meaning. Here we address this concern by using perceptually-matched stimuli and manipulating only their meaningfulness. We used two-tone images (Mooney faces) that can be perceived as meaningful faces when upright, but meaningless blobs when inverted or shuffled. In particular, we measured VWM capacity for faces vs. non-face stimuli and recognized vs. unrecognized faces while simultaneously measuring the contralateral delay activity (CDA). The CDA is believed to be a neural marker sensitive to the number of items being actively held in mind (e.g., its amplitude increases as the number of items held in VWM increases). By combining behavior and CDA we can assess the effect of meaningfulness on VWM capacity. In Experiment 1, we found that participants had higher VWM capacity for trials with more faces present compared to perceptually-matched non-faces (t(11)=3.23, p=0.008), and on trials where participants recognized more of the faces compared to trials with the same stimuli where they recognized fewer faces (t(11)=3.38, p=0.006). In Experiment 2, we found that in addition, CDA amplitudes were larger when the memory sets consisted of more faces than when they consisted of fewer faces (t(12)=2.98, p=0.01). Together these results suggest that meaningfulness plays an important role in enabling more items to be held in VWM, independent of perceptual properties. Broadly, this suggests that VWM capacity is not fixed but critically depends on what type of information is being remembered.

23.404 **Functional and anatomical characterization of visual working memory coding**
Diego Mendoza-Halliday[1](mendoz@mit.edu), Santiago Torres[3], Robert Desimone[1], Julio Martinez-Trujillo[2]; [1]McGovern Instutute for Brain Research at MIT, [2]Robarts Research Institute, Western University, [3]Department of Physiology, McGill University

Numerous studies using a variety of experimental methods have shown evidence of neural activity encoding visual working memory (VWM) representations across a wide range of cortical areas. This has led to a major controversy regarding which areas directly subserve VWM maintenance, and what role each area plays. Here we describe functional and anatomical properties of the neuronal code for VWM based on our results from neurophysiological studies in monkeys, and propose several underlying principles of brain organization that may help resolve such controversy: (i) Sustained activity encoding VWM emerges in visual association areas immediately downstream from early visual cortex, and is also present in executive areas such as the lateral prefrontal cortex (LPFC). (ii) Early visual areas exclusively encode sensory inputs; however, their synaptic activity may be modulated by higher-level areas encoding VWM, putatively influencing sensory processing. (iii) The cortical architecture of areas subserving VWM maintenance is characterized by more excitatory and less inhibitory neurons than that of areas exclusively subserving sensory processing. (iv) Population representation strength remains relatively stable throughout the memory period, yet the underlying rate code is dynamic. (v) In LPFC, coding functions vary widely across neurons, with some neurons encoding perceived and memorized visual features to similar degrees and others preferentially or exclusively encoding either one. Our results suggest that VWM coding is neither a ubiquitous property across cortical areas nor an exclusive property of high-level executive areas alone; instead, it is carried out by a finite network of areas/neurons with specialized functional and anatomical properties.

23.405 **The functional role of alpha-band oscillations for the retro-cueing benefit in visual working memory.**
Wanja A Mössing[1,2](moessing@wwu.de), Niko A Busch[1,2]; [1]Institute of Psychology, University of Münster, Germany, [2]Otto-Creutzfeld-Center for Cognitive and Behavioral Neurosciences, University of Münster, Germany

Numerous studies have shown that visual Working Memory (vWM) resources can be flexibly re-allocated after encoding by using so-called retro-cues. In this study, we investigated the functional role of alpha oscillations for this resource re-allocation. Alpha-band power (ABP) typically increases with the number of memorized items, which has been interpreted as reflecting the stronger requirement for inhibiting task-irrelevant distraction. However, recent studies have also found evidence that ABP might be associated with attention towards the target or even with the memory representation itself. Subjects (N=39) encoded two lateralized oriented lines on each trial. Half way through the maintenance interval, a retro-cue indicated which of the two items was to be remembered. After the maintenance interval, subjects reported the target's orientation. Retro-cues improved memory precision relative to a no-cue condition, in which both items had to be maintained. This benefit was paralleled by stronger ABP after no-cues compared to retro-cues. Furthermore, the reported stimulus orientations were systematically biased towards the unreported item even on cued trials, demonstrating the distracting influence of the uncued item. Importantly, ABP lateralized while the retro-cue was presented, such that power increased ipsilateral and decreased contralateral to the cued target. This lateralization pattern provides evidence against the idea that alpha oscillations participate in representing the target in the contralateral hemisphere. Instead, alpha oscillations might be associated with the retro-cuing benefit by allocating resources towards the target or by inhibiting the irrelevant distractor. Thus, we analyzed this association by correlating alpha-band lateralization with precision of the reported target and the bias towards the irrelevant distractor, respectively.

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In sum, by using retro-cues and distractors that were no longer physically present, our study complements previous research on the role of ABP, in which distractors were physically present either during encoding or during the maintenance interval.

23.406 **Alpha-band activity tracks dynamic changes in the contents of visual working memory.** Laura Rodriguez[1](laurarodrigu2014@fau.edu), Asal Nouri[1], Edward Ester[1,2]; [1]Department of Psychology, Florida Atlantic University, [2]FAU Brain Institute, Florida Atlantic University

Recent studies have shown that the contents of spatial working memory can be reconstructed from EEG oscillatory activity in the alpha frequency band (8-12 Hz; e.g., Foster et al. 2016). Here, we leverage the excellent temporal resolution of this approach to track dynamic changes in the content and quality of spatial working memory over time. Specifically, we used an inverted encoding model and a retro-cue experimental design to probe dynamic changes in representations of spatial locations following changes in task demands. We recorded EEG while participants encoded the locations of two dots. A retro cue instructed participants to remember the location of a single dot (valid cues), or to continue remembering both dots (neutral cues). Cues were presented immediately after the offset of the sample display, during the midpoint of the subsequent maintenance period, or at the end of the trial. Our preliminary findings (N = 10) suggest that while encoding locations into WM is rapid (complete ~250 ms after stimulus onset) purging a location from memory is much more sluggish (complete ~650 ms after cue onset). Location information is less robust when participants are required to remember two locations relative to one location, but representations cued locations show a modest recovery once an uncued location has been purged from memory. Both results are consistent with recent findings in the neuroimaging literature (Sprague et al., 2014; 2016). Collectively, our findings highlight the prospective utility of using alpha band EEG activity to track dynamic changes in the contents and quality of working memory representations over time.

23.407 **Evidence for concurrent activation of sequentially encoded spatial locations** David W Sutterer[1](sutterer@uchicago.edu), Edward Awh[1]; [1]University of Chicago

A robust body of work has demonstrated speeded reaction times to the last item encoded in a Sternberg task (Vergauwe et al., 2016, Oztekin, Davachi, & McElree 2010). A key debate is whether this RT benefit reflects a narrow focus of attention on the most recently presented item, in line with suggestions that working memory capacity may be limited to a single item or encoding episode. Here, we tested this hypothesis by using alpha band activity to track the time course and content of representations maintained in spatial working memory (Foster et al., 2016). This method allowed us to observe whether or not sequentially encoded items are concurrently represented during the delay period of a working memory task. On each trial, observers memorized the location of two sequentially presented colored dots while EEG was recorded. After a 1s delay period, participants were cued to report the location of one of the dots. We trained an inverted encoding model (IEM) to assess alpha selectivity for the location of each item and found robust representations of both to-be-remembered locations during the 1s delay interval consistent with the interpretation that both items are simultaneously maintained in an active state. These findings disconfirm the hypothesis that only the final item in a sequence is actively represented during the delay period. Thus, although faster RT for the final item in a sequence may reflect a higher priority or familiarity for the most recently encoded item, multiple items in a sequence can be simultaneously stored in visual working memory.

23.408 **Spatially local activity-silent working memoryh representations in human cortex.** Edward Ester[1,2](eester@fau.edu); [1]Department of Psychology, Florida Atlantic University, [2]FAU Brain Institute, Florida Atlantic University

Recent theoretical and experimental studies support an activity-silent model of (WM), where item-specific information is encoded by transient changes in synaptic efficacy. However, it is unclear whether these changes are limited to neural populations that are retinotopically mapped to the location(s) of remembered item(s) or if they extend throughout the visual field (e.g., Ester et al., 2009). Here, we evaluated these alternatives by combining EEG with a functional perturbation method (Wolff et al. 2017) to query the retinotopic specificity of activity-silent working memory representations. Participants were shown displays containing two lateralized gratings and retroactively cued to remember the orientation of the grating in the left or right visual field. During the subsequent memory period, we presented a task-irrelevant probe at the location of the cued grating (same hemifield condition), the location of the uncued grating (different hemifield condition), or in both locations (bilateral condition). Using an inverted encoding model, we recovered representations of the cued and uncued gratings that gradually decayed over the maintenance interval before probe onset. Transient representations of the cued grating (but not the uncued grating) re-emerged after probe onset, but only for the same hemifield and bilateral probe conditions. These results indicate that changes in synaptic efficacy associated with "activity silent" WM storage are restricted to neural populations that are retinotopically mapped to the location of a to-be-remembered item.

23.409 **Examining distinct neural signals that track the contents of working memory** Gisella K Diaz[1](gisella@uchicago.edu), Edward K Vogel[1], Edward Awh[1]; [1]University of Chicago

Oscillatory brain activity in the alpha-band (8-12 Hz) and slow wave EEG activity have both been strongly implicated in the maintenance of information in visual working memory (VWM). For instance, increasing VWM load leads to monotonic declines in alpha power and monotonic increases in the amplitude of a parieto-occipital negative slow wave (Fukuda et al., 2015). While both signals tracked performance, they were uncorrelated and explained distinct variance in VWM capacity. Here, we replicated this empirical pattern using color and spatial memoranda. Additionally, we tested the hypothesis that the negative slow wave is an item-based signal given that its lateralized counterpart tracks the number of individuated items in VWM despite differences in sensory stimulation (Luria et al., 2016). Meanwhile, alpha power might be a spatial index given its role in tracking spatial locations in VWM (Foster et al., 2016). To test this account, we used grouping by collinearity to manipulate the number of individuated items, while holding constant the number of locations. The stimuli were either aligned to create perceptual groups or misaligned to encourage the individuation of each element. The probability of report and response precision were higher for grouped stimuli than for ungrouped stimuli (grouping effect) and for two stimuli than for four stimuli (set size effect). Alpha power suppression was modulated by the number of display elements but not by grouping condition, which suggests that alpha power tracked the number of locations rather than the number of individuated items. The negative slow wave was also modulated by set size, though it is unclear whether the negative slow wave was affected by grouping condition given a trending grouping effect. The current work begins to shed light on a taxonomy of different delay signals, advancing our understanding of cognitive models of online memory processes.

23.410 **ABC, Easy as CDA: The contralateral delay activity robustly tracks the storage of letters in visual working memory** Jane A Burton[1](jane.ann.burton@gmail.com), Jason Rajsic[2], Geoffrey F Woodman[1,2]; [1]Neuroscience Program, Vanderbilt University, [2]Department of Psychology, Vanderbilt Vision Research Center, Vanderbilt University

Electrophysiological studies have demonstrated that the maintenance of items in visual working memory is indexed by the contralateral delay activity (CDA). The CDA is modulated by the set size of the memory array, with larger CDA amplitudes as set size increases, plateauing at visual working memory capacity. Investigations of the CDA have primarily utilized simple visual items, such as colored squares, or picture stimuli. Despite the frequent use of letter stimuli in seminal investigations of visual attention and memory, it is unknown whether visual working memory for letters also elicits a typical load-sensitive CDA. Given their close associations with language and phonological codes, it is possible that participants store letter stimuli phonologically, and not visually. The purpose of this study was to use the CDA to determine whether letter stimuli tend to be stored visually or verbally in a change-detection task. Participants completed a standard visual change-detection task while their electroencephalography (EEG) was recorded. Stimuli comprised either colored squares or uppercase consonants. Behavioral accuracy of change detection decreased with increasing set size for both colored squares and letter stimuli. The ERPs showed that a CDA was present for both colored squares and letter memory arrays, as were the capacity limited set-size

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effects for both types of stimuli, suggesting that letters did not appear to be phonologically recoded. These results suggest that, despite their verbal associations, letters also elicit the electrophysiological marker of visual working memory encoding and storage.

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23.411 **Neural measures accounting for flexibility in VSTM** Holly A Lockhart[1](hl10ze@brocku.ca), Susanne Ferber[2], Stephen M Emrich[1]; [1]Department of Psychology, Brock University, [2]Department of Psychology, University of Toronto

Recent evidence suggests that visual short-term memory (VSTM) resources can by allocated both continuously and flexibly. However, the neural mechanisms underlying this flexibility remain unclear. Previous studies have isolated the role of the intraparietal sulcus (IPS) in the maintenance of information in VSTM; however, it is unclear whether activity in this region reflects the flexible allocation of memory resources. In the currently study, we used functional magnetic resonance imaging (fMRI) to isolate the neural substrates mediating flexible VSTM resource allocation. Participants completed a delayed-estimation task in which they were cued to remember 1, 2, or 4 items with 100% validity, or in the critical condition, participants were cued to 1 item with 50% validity. This manipulation requires flexible resource allocation across four items. This task was previously shown to reliably influence the distribution of memory resources in a flexible manner according to the cueing probability (Emrich, Lockhart, & Al-Aidroos, 2017). IPS activity showed the expected increase in activity for the memory load manipulations. In the flexible allocation condition the IPS activity demonstrated a level of activity that suggested all four objects in memory while behavioral evidence confirmed that memory resources were flexible allocated. Several regions were identified to be more active in the flexible memory allocation condition relative to a load four condition, the largest of which were the bilateral insula, cingulate gyrus, and right dorsolateral prefrontal cortex (dlPFC). Additionally, mixed linear effects modeling revealed IPS activity did not significantly predict absolute recall error; in contrast, right dlPFC activity significantly predicted absolute recall error. These results suggest that VSTM precision is in part determined by flexible resource allocation mediated by top-down attentional mechanisms.

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23.412 **Temporal dynamics of visual working memory representations across human cortex** Thomas C Sprague[1](tsprague@nyu.edu), Wei Ji Ma[1,2], Clayton E Curtis[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

The contents of visual working memory (WM) can be decoded from the spatial patterns of delay period fMRI activation in occipital, parietal, and frontal cortices (Serences et al, 2009; Harrison & Tong, 2009; Jerde et al, 2012; Lee et al, 2013; Albers et al, 2013; Sprague et al, 2014; Ester et al, 2015; van Bergen et al, 2015; Rahmati et al, 2017). Here, using fast-sampling (750 ms) fMRI, we characterized the temporal dynamics of these WM representations across the human cortex from initial encoding to the end of maintenance. On each trial, participants generated a memory-guided saccade to the location of a target stimulus briefly presented prior to a 12-second-long retention interval. We applied a linear inverted encoding model (IEM) to reconstruct the remembered spatial position at each time point during the trial from cortical activation patterns (Sprague et al, 2014), focusing analyses on retinotopic regions independently-defined using voxel receptive field mapping in occipital, parietal, and frontal cortex (Mackey et al, 2017). We observed an initially-strong representation in V3AB, followed by simultaneous cascades backward from V3 to V2 to V1 and forward along retinotopic IPS over the next several seconds. In many regions, representations remained stable throughout the delay period, but waxed and/or waned in their strength. We confirmed this stability by evaluating the extent to which an IEM estimated using data from each time point could generalize to others (King & Dehaene, 2014). We found evidence for stable representational geometry across the entire 12 s delay in extrastriate visual and parietal cortex, further supporting the notion that WM representations are instantiated via persistent stable codes. This dynamic routing of information suggests a nuanced perspective on the role of different brain regions during WM maintenance, demonstrating that each region represents information most strongly at different points in time.

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23.413 **But wait, there's more! Six bilateral sensory-biased regions in human frontal cortex.** Abigail Noyce[1](anoyce@bu.edu), Sean M. Tobyne[2], Samantha W. Michalka[3], Barbara G. Shinn-Cunningham[4], David C. Somers[1]; [1]Psychological and Brain Sciences, Boston University, [2]Graduate Program in Neuroscience, Boston University, [3]Olin College of Engineering, [4]Biomedical Engineering, Boston University

Our lab has previously identified four bilateral sensory-biased regions of human lateral frontal cortex (LFC; Michalka 2015; Noyce 2017). Two visual-biased regions in superior and inferior precentral sulcus are interleaved with two auditory-biased regions. fMRI resting-state functional connectivity between posterior sensory cortex and LFC suggested additional sensory-biased regions extending rostrally along the inferior frontal sulcus and frontal operculum (Tobyne 2017). We collected fMRI while subjects (n=15) performed visual and auditory 2-back working memory (stimuli were face photographs and animal vocalizations, respectively). Directly contrasting visual 2-back with auditory 2-back revealed additional bilateral visual- and auditory-biased structures in the middle inferior frontal sulcus and the frontal operculum, respectively, yielding a total of three visual-biased and three auditory-biased regions within human LFC. We previously demonstrated (Noyce 2017) that visual-biased LFC regions participate significantly in auditory working memory, but not vice versa. Here, we extend that analysis of multiple-demand behavior these newly identified regions. We will also examine resting-state functional connectivity among sensory-biased LFC regions, modality-general LFC regions, and posterior sensory cortex. Our results suggest that preferences for one sensory modality may be an effective approach for parcellating large portions of human LFC.

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23.414 **Dynamic reconfiguration of global network and regional functional connectivity when comprehending visual narratives** Hayoung S Song[1,2](omasong17@gmail.com), Bo-yong Park[1,3], Hyunjin Park[1,4], Won Mok Shim[1,2]; [1]Center for Neuroscience Imaging Research, Institute for Basic Science (IBS), [2]Department of Biomedical Engineering, Sungkyunkwan University (SKKU), [3]Department of Electronic, Electrical and Computer Engineering, Sungkyunkwan University (SKKU), [4]School of Electronic and Electrical Engineering, Sungkyunkwan University (SKKU)

When comprehending visual narratives, the human brain constantly accumulates and integrates incoming information to make a cohesive representation of event structures. Recent studies have suggested that the brain fluctuates between globally segregated and integrated states, and such fluctuation is modulated by the cognitive process engaged at the moment (Shine et al. 2016). Here, we ask whether the dynamic reconfiguration of brain networks can be driven by changes in cognitive states during visual narrative comprehension. Using fMRI, we investigated network- and regional-level changes when subjects were engaged in comprehending scrambled versions of the silent films. Whole-brain time-resolved FCs were mapped, and the graph indices were compared between the time points when understanding of the narrative actively occurred, and the time points when understanding occurred to a lesser degree. Global modularity was low during times of high narrative understanding, implying that the modular structure of the brain was tightly integrated when the degree of information integration was high. Regions within the default mode network (DMN) and frontoparietal network significantly increased modular connections during times of high narrative understanding; specifically, medial prefrontal cortex, posterior cingulate cortex and precuneus increased its across-modular connections, whereas frontal regions increased within-modular connections. Similar patterns of changes were not shown when subjects repeatedly watched the same film, indicating that these FC changes were not driven by the

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physical characteristics of visual stimuli. Furthermore, we examined whether the moment-to-moment pattern of regional FCs can predict the degree of narrative understanding. Decoding analysis using selective FCs revealed that it was possible to predict the degree of understanding at a specific time point of a novel subject, and even for a novel film. Our findings suggest that the brain adaptively regulates its modular structure by coordinating connections of the DMN and frontoparietal network, upon dynamically updating representation of visual narrative structures.

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23.415 **The neural basis of binding errors in visual working memory** Kartik K Sreenivasan[1](kartik.sreenivasan@nyu.edu), Ainsley Temudo[1], Vahan Babushkin[1]; [1]Division of Science and Mathematics, New York University Abu Dhabi

Memory errors are a window into the capacity limits that famously constrain visual working memory (VWM). When subjects maintain multiple items in VWM and are asked to report a feature of one item, they sometimes mistakenly report the feature of another item. This is referred to as a binding error. Understanding the neurophysiology underlying binding errors can provide key insights into how features are bound together in VWM. One biophysiological model (Barbosa and Compte, 2015) suggests that object features are stored as pairs of bumps in individual attractor networks, and that features are bound via network oscillations. This model predicts that binding errors can result from disruptions in the oscillatory pattern of the network – specifically in the alpha/beta range (8-25 Hz). Our aim was to validate this model using magnetoencephalography (MEG) to measure network oscillations in a task designed to induce binding errors. On each trial, subjects briefly saw 3 circles and had to remember their colors and locations over a memory delay. After the delay, they were sequentially cued to report the location of each circle (via a central color cue). Using a maximum likelihood approach, we assigned each response a likelihood of being a binding error. Trials with likelihoods greater than 0.7 were considered binding error trials. We computed a phase preservation index (PPI) for each MEG sensor separately for trials with and without binding errors. PPI measures the consistency of the relationship in oscillatory phase across trials. Binding errors were associated with significantly reduced alpha (8-12 Hz) PPI during the memory delay in frontoparietal sensors. This pattern of reduced frontoparietal alpha phase consistency was specific to binding errors, as opposed to other VWM errors. This finding provides initial support for the idea that object features are bound via low-frequency network oscillations in VWM.

23.416 **Frontal visual field maps mediate noise resilience of working memory** clayton e curtis[1,2](clayton.curtis@nyu.edu), wayne e mackey[1]; [1]Department of Psychology, NYU, [2]Center for Neural Science, NYU

Working memory (WM) extends the temporal period within which neural representations can be integrated and transformed, enabling a vast array of cognitive abilities. Conversely, WM has severe capacity limitations, and varies widely between individuals and across the lifespan. Psychophysical studies and computational models indicate that random noise corrupts the quality of WM representations (Wilken & Ma, 2004; Bays, 2015). Here, we combine computational modeling, fMRI, and TMS to test hypotheses about the neural basis of WM limits. First, we simulated the fidelity of WM in various sizes of neural networks and found that the size of the network population affected WM precision. Second, we used population receptive-field mapping (Mackey, Winawer, & Curtis, 2017) to estimate the size of the precentral sulcus (sPCS) visual map across participants. Consistent with the neural network results, we found a correlation between the size of sPCS and WM precision. Finally, we applied TMS to the sPCS during the delay period of a WM task to simulate the addition of noise in the population. We found that sPCS map size mediated the detrimental effects of TMS on WM accuracy. Specifically, TMS applied during the retention interval caused a greater reduction in WM accuracy in subjects with smaller sPCS maps. Interestingly, subjects with large maps were resilient and were hardly affected by TMS. Together, these results indicate that 1) the sPCS is necessary for accurate WM, 2) it's size may place a hard constraint on WM resources, and 3) individual differences in it's size may predict one's resilience or the degree to which WM representations are corrupted by noise.

23.417 **Frontal and parietal cortex make distinct contributions to the storage and allocation of resources that support WM** Grace E. Hallenbeck[1](geh261@nyu.edu), Alfredo D. Bolaños[1], Thomas C. Sprague[1], Clayton E. Curtis[1,2]; [1]Psychology Department, New York University, [2]Center for Neural Science, New York University

Persistent activity in human frontal precentral and intraparietal sulci (PCS and IPS) sustains working memory (WM) representations over retention intervals (Jerde et al., 2012). Moreover, the fidelity of WM also depends on the efficient allocation of memory resources among multiple items competing for representation (Klyszejko et al., 2014). Here, we tested whether PCS and IPS may contribute differentially to the allocation of WM resources. We measured the effect on WM accuracy that repetitive transcranial magnetic stimulation (TMS) had when applied to retinotopic frontal and parietal cortex during the delay period of a visual spatial WM task requiring an uneven distribution of resources. On each trial, participants generated a memory-guided saccade (MGS) to the location of one of two items maintained over a memory delay. Critically, they were cued before the trial which of the two items was more likely to be tested, and therefore, should allocate more WM resources to prioritize the storage of that item. We applied rTMS during the delay period to superior PCS (sPCS) and IPS (IPS2) defined using a novel fMRI-based population receptive field (pRF) mapping technique (Mackey et al., 2017). In the absence of rTMS, MGS were more accurate to high-compared to-low prioritized targets, confirming past work demonstrating the flexible allocation of WM resources (Klyszejko et al., 2014; Emrich et al., 2017; Bays et al., 2009). Perturbation to IPS2 caused a non-selective worsening of MGS accuracy to both high and low priority targets. In contrast, sPCS perturbation removed the benefit of priority, as if the strategic allocation of resources was impaired. These results support a framework whereby sPCS enables an efficient allocation of WM resources, while IPS supports WM representations themselves. Together, these results demonstrate the nuanced role each region plays with regard to representing versus prioritizing information.

23.418 **The benefits of combined brain stimulation and cognitive training: a pilot study** Sara Assecondi[1](s.assecondi@bham.ac.uk), Kimron L Shapiro[1]; [1]School Of Psychology, University of Birmingham, UK

Average life expectancy has increased during the last century, resulting in an increasing aging population. It is therefore of paramount importance to develop new strategies to address age-related cognitive decline. Recent advances in safe, non-invasive direct current stimulation (tDCS) combined with cognitive training show tremendous promise as means of slowing cognitive decline in the ageing population. In this pilot study we address the benefit of combined tDCS and cognitive training on working memory. Twelve participants receiving working memory training were randomly assigned to two groups: an active (rtDCS) group or a control (SHAM) group. Individuals included in the active group received 20 min of tDCS on the right dorsolateral prefrontal cortex while completing the cognitive training, whereas participants in the control group completed the cognitive training alone. The training task consisted of an adaptive visuo-spatial N-back task. Each participant completed 7 sessions of training, and pre- and post-training assessment sessions, to measure transfer of training to other cognitive domains. Our pilot data suggest that the concurrent use of cognitive training and tCS has a beneficial effect on the rate at which participants improve during the training. This is in agreement with recently published animal data (Krause, CurrBiol, 2017). The data further suggest evidence of transfer to a non-spatial visual task, an important hallmark of successful training. This pilot study has two main limitations. First, all participants are young (20-35), hence they are already at ceiling of their memory capacity. Second, the sample size is very limited, due to the complexity of the design (multiple sessions), and a larger sample would be needed to draw firmer conclusions. Notwithstanding these limitations, we believe that our approach represents a viable path to reveal the potential of combined brain stimulation and cognitive training to improve cognitive performance in both normally and abnormally ageing adults.

3D Perception: Mechanisms and models

Saturday, May 19, 8:30 am - 12:30 pm, Pavilion

23.419 **Generalized representation of stereoscopic surface in V3A** Zhen Li[1](li_zhen22@qq.com), Hiroaki Shigemasu[2]; [1]Graduate School of Engineering, Kochi University of Technology, [2]School of Information, Kochi University of Technology

Although it has been shown that many visual cortical areas process binocular disparity, it is still not clear how these areas are involved in stereoscopic 3D surface perception. In this study, we conducted fMRI experiment to provide evidence whether ROIs are involved in 3D surface by comparing the accuracy of classifying different 3D surfaces using multi-voxel pattern analysis and further investigated what levels of process for the surface perception are involved. The ROIs were a defined by standard retinotopic mapping in early visual areas and localizers for higher areas. Random dot stereograms were used to depict hemi-cylindrical convex and concave surfaces. There were two types of hemi-cylinders: horizontally positioned defined by shear disparity and vertically positioned defined by compression disparity. We also showed each type of surfaces at two different depth positions to investigate whether the process of the surfaces is independent from the depth position. Linear support vector machines were trained to classify whether the stimuli were convex or concave. Two types of accuracy assessments were performed to investigate the generalized representation of 3D surfaces: (1) Same-type stimuli validation: trained on surfaces defined by shear or compression disparity and tested on the surfaces defined by the same type of disparity. (2) Cross validation: trained on surfaces defined by shear or compression disparity and then tested on the surfaces defined by the different type of disparity. Results showed that while classification accuracies were significantly higher than chance level only for same-type stimuli in V1 and V2, V3A showed classification accuracies were significantly higher for both same-type and cross validation. These results suggest that V3A is related to more generalized process of 3D surface perception irrespective of different depth positions and different disparity types, while V1 and V2 are related to low level process of disparity information.

23.420 **7T fMRI reveals ocular dominance layers of the human LGN** Yazhu Qian[1](foolmounts@hotmail.com), Peng Zhang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences

The lateral geniculate nucleus (LGN) of the thalamus is an important subcortical structurerelaying visual information from retina to the primary visual cortex, but the function of the human LGNs is not well understood. Theprimate LGNs consist of six main layers of neurons with distinct functions and anatomies.The ability to resolve layer-specific activities of the LGN non-invasively in the human brainhas important implications. In this study, we tested whether ultrahigh field fMRI at 7T coulddistinguish eye-specific activities and revealocular dominance layers of the human LGN.Achromatic checkerboard patterns werepresented monocularly at full contrast and counterphase flickering at 7.5Hz. BOLD signals in the LGNs were acquired with gradient Echo EPI at 1.2mm isotropic voxels, and balanced-SSFP sequence with 1x1x2mm voxels. Results showed a highly reliable eye-dominance pattern for each LGN of three subjects, which is a sandwiched organizationof three layered sections, arranged in the medial-ventral to dorsal-lateral direction. Themiddle section showed greater response to the ipsilateral eye, while the surrounding two hada response bias to the contralateral eye. This pattern is consistent with the fact that layer 2, 3 and 5 of the LGN receive visual input from the ipsilateral eye, while layer 1, 4 and 6 receive information from the contralateral eye.The pattern was highly consistent between odd and even runs within each scanning session, as well as across different sessions. To further confirm this finding, we ran a simulation test based on Nissl stained images of the human LGN at 20μm resolution, with the BOLD point-spread function taken into account. The simulation results showed-identical patterns as found with fMRI. We conclude that BOLD fMRI at 7T is capable toresolve layer-specific activities in the human LGN, which has important implications to understand its function in visual perceptionand cognition.

23.421 **Columnar Neural Mechanisms Underlying Vertically Asymmetric Global Visual Processing** shahin nasr[1, 2](shahin@nmr.mgh.harvard.edu), Roger B.H. Tootell[1, 2]; [1]Athinoula A. Martinos Center for Biomedical Imaging, Massachusetts General Hospital, Boston, MA, [2]Department of Radiology, Harvard Medical School, Boston, MA

Global visual processing refers to the detection of large scale coherences and low spatial frequency (SF) cues that comprise a meaningful gestalt. Humans perceive stimuli more globally when presented within the lower (rather than the upper) visual field. This vertical asymmetry is likely due to higher ecological relevance of global visual processing of near (within arm's reach) compared to farther objects (Previc, 1990) that, in natural scenes, are more frequently present within the lower rather than the upper visual field (Yang and Purves, 2003). However, neural mechanisms that underlie this phenomenon are still mostly unknown. In this study, we used high-resolution fMRI (0.8-1.0 mm isotropic voxels), collected in an ultra-high field (7T) scanner, to study global processing in depth sensitive (disparity-selective) cortical columns within human visual areas V2, V3 and V3A (n=10). Using this technique, we measured activity evoked within these columns by retinotopically-equated near vs. far stimuli, generated by disparity-varying random dot stereograms. Our findings indicated that the extent of vertical asymmetry in global visual processing (measured behaviorally) varies across individuals correlated with the level of fMRI response evoked by near (but not far) stimuli in their V3A. To better clarify V3A role in global processing, we compared the fMRI response to a wide range of 1D and 3D SFs in near- and far-preferring clusters within disparity-selective columns. We found that, in V2, V3 and V3A, near-preferring clusters (compared to far-preferring ones) responded more selectively to low SFs (< 0.5 cycle/degree), important for global visual processing. However, compared to V2 and V3, the preferred SF was significantly lower in V3A disparity-selective columns, suggesting a stronger link between the vertically asymmetric global processing and the function of near-preferring clusters within V3A compared to V2 and V3. These findings highlight the importance of fine-scale cortical structures in controlling human behavior.

Acknowledgement: NIH

23.422 **Contextual feedback to V1 neurons shapes binocular matching** Reuben Rideaux[1](rr513@cam.ac.uk), Andrew E Welchman[1]; [1]University of Cambridge

Humans infer three dimensional structure of the visual environment by calculating the disparity between images projected into the left and right eyes (i.e., stereopsis). Stereopsis emerges in area V1, where neurons begin receiving binocular input from the lateral geniculate nucleus. Feedforward computations of stereopsis are well established, yet the role of feedback/lateral connections remains unknown. Here we test whether feedback/lateral signals induced by spatial context influence the activity of binocular neurons in V1. We used fMRI to measure activity in the primary visual cortex of participants while they viewed ambiguous "wallpaper" stereograms, i.e., square wave gratings presented with a 180° phase offset between the left and right eyes, which could be perceived as either near or far. We manipulated perceived (near/far) depth of the wallpaper by framing it with either a light- or dark-grey background. Using flickering checkerboard localizers, we identify regions of V1 with receptive fields corresponding to either the frame or wallpaper sections of the stimulus. The near/far identity of the wallpaper pattern was ambiguous; thus, perceived depth could only be inferred by the identity of the frame. Despite this, using multi-voxel pattern analysis we were able to reliably decode perceived depth from the activity of voxels in V1 corresponding to the ambiguous wallpaper region. We then quantified the strength of the depth representation across retinotopic areas and found we were able to reliably decode perceived depth from areas V3A, V4, and V7. These results indicate the involvement of feedback/lateral connections in shaping the activity of disparity selective neurons in V1 during binocular matching.

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23.423 Depth from Motion Parallax is Disambiguated by Pursuit Eye Movements in the Absence of Vertical Perspective Shanda Lauer[1](shanda.lauer@my.ndsu.edu), Mark Nawrot[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

The pursuit theory of motion parallax (MP) posits that the visual system uses an internal pursuit eye movement signal to disambiguate the relative depth of retinal image motion. Support is found in psychophysical, modeling, and neurophysiological studies. However, a contrary view is that this depth-sign disambiguation is provided solely from vertical perspective information, and not from the pursuit eye movement system (Rogers, 2016). In a partial replication and extension of previous work, the current set of experiments investigated whether vertical perspective is necessary for the disambiguation of depth from MP. In four different conditions, 10 observers indicated the perceived depth phase (2AFC) of computer-generated random-dot MP stimuli. In the first condition, translating stimuli were presented to observers on a flat CRT monitor providing both vertical perspective and pursuit eye movement cues. Subsequent conditions were designed to eliminate perspective cues, while still eliciting pursuit eye movements. In the second condition, the stimuli were projected on the face of a hemi-spherical Elumens Visionstation, with observer's eye positioned at the radius point. In the third condition, the stimuli were presented on an LCD display that mechanically translated in a single +/- 6 deg arc around the observer's eye position. In the fourth condition, stimuli were presented on an LCD display that mechanically oscillated in a +/- 6 deg arc for a 55 second presentation duration while observers indicated perceived depth phase. In all conditions observers reliably reported perceived depth phase consistent with that predicted by the pursuit theory of MP, despite the absence of vertical perspective cues. Previous work has shown changes in vertical perspective produced by stimulus translation are ineffective for the disambiguation of depth from motion parallax in the absence of pursuit eye movements. Therefore, we conclude that vertical perspective cues are unnecessary for the disambiguation of depth from MP.

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23.424 Temporal properties of persistence and change in perceived depth from motion parallax Mark Nawrot[1](mark.nawrot@ndsu.edu), Breanna Thompson[1], Shanda Lauer[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Successful navigation by a moving observer requires rapid integration of visual depth information to construct a quickly updated 3D model of the environment. While unambiguous depth from motion parallax (MP) is generated with brief presentations (~30 msec), temporal properties for persistence and updating are unknown. Ten observers reported perceived depth (2AFC) upon viewing computer-generated random-dot MP stimuli. Stimulus presentation used a 120 Hz CRT with stimulus timing verified with an independent 20 MHz clock. MP stimuli made two oscillations, with each of the 4 lateral translations having the same duration (t). To maintain a consistent depth depiction, the direction of local stimulus dot movement reversed with each reversal in stimulus translation. Duration, t, was varied in two interleaved staircases, one for each initial direction of stimulus translation. Condition 1 confirmed that observers accurately recover unambiguous depth from MP with brief presentations (t = 34msec). Condition 2 found that observers require a longer duration (t = 93msec) to determine whether the last stimulus translation depicted MP depth, or was flat (no local dot movements). Condition 3 introduced a blank delay (duration = t) before the last translation in which observers made the same depth/no depth discrimination, which reduced the necessary presentation duration (t = 76msec). Condition 4 revealed that the discrimination of an MP depth reversal during the last stimulus translation requires a brief (t = 47msec) presentation. These results suggest that depth from MP can be recovered and updated in very brief temporal intervals, which is likely a useful property for an observer who is often shifting gaze during translation through a cluttered environment. However, these internal depth models appear to persist for much longer in the absence of depth information, which is perhaps useful in the maintenance of a consistent depth interpretation during blinks or brief obstructions of fixation.

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23.425 Orientation tuning for spatial vision and stereopsis: Factor analysis of individual differences in contrast and disparity thresholds Ignacio Serrano-Pedraza[1,2](iserrano@ucm.es), Douglas J. Boegaerts[1], Jenny C. A. Read[2], David H. Peterzell[3]; [1]Faculty of Psychology. Complutense University of Madrid, Madrid, Spain, [2]Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, UK, [3]College of Psychology, John F. Kennedy University, Pleasant Hill, CA, USA

Both 3D corrugations defined by binocular disparity and luminance-modulated sinusoidal stimuli are served by frequency- and orientation-tuned processes, but the number and nature of these mechanisms are not fully understood. Nor is the relationship between stereoscopic and luminance sensitive mechanisms. Here, we investigated the orientation processes that serve the detection of stereoscopic and luminance-modulated sinusoidal stimuli, using factor analyses of individual differences. In 30 participants, we used Bayesian staircases to measure (1) stereo-thresholds using sinusoidal corrugations defined by binocular disparity, and (2) contrast thresholds for detecting luminance-modulated Gabor patches. Seven orientations ranged from 0° to 90° in steps of 15°, with spatial frequency set to 0.1cpd. Thresholds for stereo showed anisotropy, increasing sigmoidally from 90° (horizontal) to 0° (vertical), while there was no oblique effect for luminance. Correlational and factor analyses for stereo thresholds revealed two broadly tuned, highly intercorrelated factors, whereas for luminance, we found three or four narrowly tuned factors almost independent of factors for other orientations. Thresholds for stereo and luminance were uncorrelated; factors for the two were independent. For stereo, finding two highly interdependent orientation processes clarifies why we (Peterzell, Serrano-Pedraza, Widdall, & Read, 2017, Vision Research) found factors tuned to high and low spatial frequencies, but which showed no selectivity for orientation (0° and 90° corrugations). The two stereo orientation factors, which seem necessary to explain anisotropy, could not be discerned in our previous study because of their broad tuning and interdependence compared to spatial frequency tuned factors, and because only two orientations were tested. For luminance, finding multiple orientation factors is consistent with previous research (Phillips & Wilson, 1984), and suggests that contrast sensitivity is determined cortically, and not by earlier circularly symmetric processes (e.g. magnocellular, parvocellular processes). The independence of factors for perceiving 3D corrugations and luminance stimuli suggests different processing streams.

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23.426 The visual kinetic depth effect is altered with Parkinson's disease Keith D White[1](kdwhite@ufl.edu), Frank M Skidmore[2], Kenneth M Heilman[3]; [1]Department of Psychology, University of Florida, Gainesville FL 32611 USA, [2]Department of Neurology, University of Alabama, Birmingham AL 32523 USA, [3]Department of Neurology, NF/SG VA Medical Center, Gainesville FL 32608 USA

Background People with Parkinson's disease (PD) have sparse dopamine and often have visual-perceptual disorders. The goal of this study was to learn if they can develop a three dimensional (3D) percept that depends on the kinetic depth effect; that is, the viewer's ability to spatially integrate over time images that are moving along many trajectories. Methods Sixteen patients with PD and 12 healthy matched controls were presented with stimuli that were comprised of a circular region of randomly placed dots that moved as orthographic projections of a sphere. With a normal kinetic depth effect, the unidirectional Training stimuli appear as an opaque rotating ball and the bidirectional Test stimuli appear as a rotating transparent ball. Results Whereas all controls and all PD patients reported seeing the unidirectional Training stimuli as a rotating ball, the patients with PD were significantly less likely to report the bidirectional Test stimuli appearing as a 3D "ball" than were the healthy participants. Instead, seven PD patients often reported these bidirectional stimuli appeared "flat." When viewing stimuli that were mixtures of unidirectional and bidirctional frames, adding some proportion of unidirectional

motion rescued the reports of "ball" for these seven patients. Conclusions This study has revealed that some patients with PD have impaired spatio-temporal integration of bidirectional visual motions, but the mechanism accounting for this loss, as well as why only some patients had this deficit, needs further study. When the driver of a moving vehicle fixates upon a stationary target in the surroundings, bidirectional retinal image motions may occur. Failure to perceive 3D structure in such moving scenes can be plausibly suspected to contribute to adverse events such as auto accidents. Drivers with PD have been reported to have increased risk for auto accidents.

Acknowledgement: N/A

23.427 **Use of local image information in depth edge classification by humans and neural networks** Krista A Ehinger[1](kehinger@yorku.ca), Wendy J Adams[2], Erich W Graf[2], James H Elder[1]; [1]Centre for Vision Research, York University, [2]Department of Psychology, University of Southampton

Background. Humans can use local cues to help distinguish edges caused by a change in depth from other types of edges (Vilankar et al., 2014). But which local cues? Here we use the SYNS database (Adams et al., 2016) to automatically label image edges as depth or non-depth and use this to compare the edge cues used by human and deep neural networks (DNN) observers for this task. Labelling. We employed a multi-scale algorithm (Elder & Zucker, 1998) to detect edges in both 2D color imagery and registered 3D range images and used a probabilistic method to associate image and range edges that match in location and orientation. Image edges with depth contrast >0.1 were labelled as depth edges. Image edges without a range edge match were labelled as non-depth edges. Methods. Observers viewed square image patches, each centered on an image edge, ranging in size from 0.6-2.4 degrees (8-32 pixels) wide. Human judgements (depth/non-depth) were compared to responses of a DNN trained on the same task. Results. Human performance increased with patch size from 65% to 74% correct, but remained well below DNN performance (82-86% correct). Agreement between human and DNN observers was above chance but below agreement between pairs of human observers. For both human and DNN observers, depth edge response increased with luminance contrast. However, for human observers, darker and bluer patches were more likely to be judged as depth edges, whereas for DNN observers, greener patches were more likely to be judged as depth edges. Also, for humans, the role of color increased with patch size, whereas for the DNN it decreased with patch size. Conclusion. Several local luminance and color features provide useful cues for depth edge detection. A DNN model provides a partial account of how human observers employ these cues.

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23.428 **Modeling 3D Slant Perception: Bootstrapping 3D Affine Structure to Euclidean** Xiaoye M Wang[1](wang492@indiana.edu), Mats Lind[2], Geoffrey P Bingham[1]; [1]Department of Psychological and Brain Science, Indiana University Bloomington, IN, USA, [2]Department of Information Technology, Uppsala University, Uppsala, Sweden

Lind et al. (2014) proposed a Bootstrapping model to account for results of using large continuous perspective change to recover the unknown affine scaling factor in the perception of 3D polyhedral shape. The model assumes 3D affine structure and bootstraps up to Euclidean. The current study extended application of this model to 3D slant perception using monocular optic flow. Because non-coplanar points (not typical in slant displays) are theoretically required for the affine structure, we tested slant judgments of strictly planar surfaces compared to surfaces with non-coplanar points. We compare simulations with empirical results from human observers to evaluate the model's effectiveness. Methods We simulated planar surfaces defined by a series of points, both in displays and in model simulations. We used perspective projections to obtain visual coordinates and relevant information associated with the surface points, to which we applied the bootstrapping model to derive predicted slants as a function of different amounts of continuous perspective change and visual noise. We compared the simulation results with judgment results. Results We found that the model failed to generate accurate predictions of slant when the surface was planar, lacking non-coplanar points. However, when non-coplanar points were introduced, the model prediction became accurate. As predicted, judgments became accurate in the face of representative levels of visual noise with ≥ 45° perspective change. Conclusion The Bootstrapping model and empirical data showed that first, optical information allows perception of 3D affine (or relief) structure, and secondly, sufficiently large perspective change enables application of affine operations described by the model to bootstrap affine structure to Euclidean structure via the required scaling constant.

23.429 **3D motion direction estimation – Model predictions and data** Kathryn Bonnen[1,3](kathryn.bonnen@utexas.edu), Thaddeus Czuba[2,3], Jake A Whritner[2,3], Austin C Kuo[3], Alexander C Huk[1,2,3], Lawrence K 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 have recently developed a neural model for coding 3D motion direction in primate area MT. By incorporating the geometry of retinal projection, it encodes motion direction with a bank of strikingly non-Gaussian tuning functions. The model makes surprising predictions about how performance should change as a function of stimulus location (i.e. across viewing distance and eccentricity). In this work, we used a motion direction estimation task to test these predictions. We manipulated viewing distance (20cm, 31cm, or 67cm) across blocks of trials. In order to manipulate viewing distance precisely at such short distances, we built a rear-projection system mounted on rails (ProPixx 3D projector; Screen Tech ST-PRO-DCF) that can be easily adjusted for viewing distances from 20cm to 270cm with a head-fixed subject. During each trial (1s), a spherical volume of low-contrast light and dark dot stimuli were rendered with full stereoscopic cues (disparity, expansion, and size-change) moving at one of three speeds (5cm/s, 7.75cm/s, or 16.75cm/s). The stimulus volume was three-dimensionally scaled for each viewing distance to maintain a consistent 5° visual angle (1.75cm, 2.70cm, 5.85cm diameter, respectively). Subjects reported the perceived 3D direction of motion using a physical knob to adjust the angle of a stereoscopic response arrow also rendered in the virtual 3D space. Direction estimation error varied sinusoidally as a function of motion direction, consistent with a frontoparallel motion bias. Crucially—and as predicted by the model—subjects often confused the sign of the z-axis (depth) component of the 3D motion direction, and this effect increased with increased viewing distance. Taken together, these results support the notion that that 3D motion perception performance is dependent on motion direction, viewing distance, and environmental speed as predicted by our model of encoding in MT.

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23.430 **Dissociations in ideal and human observer visual search in 3D images** Miguel Angel Lago Angel[1](lago@psych.ucsb.edu), Craig K Abbey[1], Miguel P Eckstein[1]; [1]Department of Psychological & Brain Sciences, University of California Santa Barbara, Santa Barbara, CA. 93106, USA

Introduction: Modern medical, aerial and satellite imaging generate increasingly larger volumes of images. For medical imaging, the use of volumetric data has drastically increased, although there is no full understanding of its impact on human search. When compared to 2D imaging, 3D data increases the information by providing various slices of the signal's volume but also increases the search space and the spatiotemporal uncertainty of the signal's location. Here, we evaluated human vs. ideal observer performance in 2D and 3D search for different signals with different detectabilities in the human visual periphery. Methods: Seven observers searched for a larger 3D-Gaussian signal (0.50 deg for its central slice) or a smaller sharp-edged sphere (0.13 deg) embedded in 2D or 3D 1/f2.8 isotropic filtered noise. Human observers were cued to find (Yes/No task; 50% target prevalence) one of the two signals in the 3D volume or in a 2D slice (central slice). Results: Ideal observer performance (d') increased from 2D to 3D by a factor of ~12 for the sharp sphere and ~170 for the Gaussian, in d' units. In contrast, human search performance increased for the Gaussian signal (2D $d' = 1.28 \pm 0.14$ 3D $d' = 2.8 \pm 0.35$; $p < 0.01$) but decreased for the smaller spherical signal (2D $d' = 3.92 \pm 0.311$ 3D $d' = 2.3 \pm 0.39$; $p < 0.01$). Analysis of human gaze behavior shows an increase (7 times higher) in search errors (not foveated) for the small signal in 3D images suggesting that its lower detectability in the visual periphery mediates the decrease in 3D search performance. A foveated search model correctly predicts the lower detectability of the small signals in 3D images.

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We conclude that the foveated nature of human visual processing, not captured by the ideal observer, has important implications on the effectiveness of 3D search.

23.431 **Stereo Slant Estimation of Planar Surfaces: Standard Cross-Correlation vs. Planar-Correlation** Can Oluk[1,2](cnoluk@gmail.com), Kathryn Bonnen[1,3], Johannes Burge[4], Lawrence K Cormack[1,2,3], Wilson S Geisler[1,2,3]; [1]Center for Perceptual Systems, University of Texas at Austin, Austin, TX, USA, [2]Department of Psychology, University of Texas at Austin, Austin, TX, USA, [3]Institute for Neuroscience, University of Texas at Austin, Austin, TX, USA, [4]Department of Psychology, University of Pennsylvania, Philadelphia, PA, USA

Estimating the three dimensional structure of surfaces is an essential visual task. We studied how the visual system uses binocular information to estimate the slant of planar surfaces. Specifically, we compared how well two candidate computational models explain the data from a psychophysical experiment, where participants were asked to decide whether a textured test plane is more or less slanted than a textured reference plane. Surfaces were viewed from 100 cm and reference plane slants ranged 0 to 50 deg. The stimuli were designed so that performance depends primarily on stereo information. In general, slant discrimination thresholds were found to decrease with baseline slant and to increase with the contrast of white noise added to the test plane. Fronto-parallel bias also increased with noise contrast. Although individuals varied in overall performance, the variation was mostly explained by a single efficiency (scaling) parameter. Our first candidate model was the standard cross-correlation model for disparity estimation, which has been successful in explaining various psychophysical results and can be implemented in a biologically plausible fashion. In this model, estimation of surface slant involves estimating disparities at various surface locations and then estimating the gradient of those disparities across the surface. However, standard cross-correlation implicitly assumes that the surface is locally fronto-parallel, which is not true for slanted surfaces. Our second candidate model, the planar cross-correlation model, does not suffer from this assumption and is motivated by the computations needed for ideal estimation of slant for planar surfaces. The planar cross-correlation model simultaneously estimates slant and depth in an image region by incorporating information about the expected differences in the left and right eye images as a function of distance and slant. We find that the standard cross-correlation model better explains discrimination thresholds, but neither model predicts the fronto-parallel bias.

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23.432 **The effect of interocular contrast on disparity tuning in primary visual cortex** Laura Palmieri[1,2](palmierilaurapi@gmail.com), Sid Henriksen[1,2], Jenny C.A. Read[1], Bruce G. Cumming[2]; [1]Institute of Neuroscience, Newcastle University, [2]National Eye Institute, National Institutes of Health

Reducing contrast has little effect on psychophysical stereoacuity, except at very low contrast. Differences in contrast between the eyes are more disruptive. The effect of contrast on disparity selectivity in cortical neurons has been investigated only in the cat with grating stimuli. Here we report the effects of stimulus contrast on disparity selectivity in 38 disparity-tuned neurons recorded from V1 of the awake fixating primate. The stimulus was a dynamic 1-dimensional noise pattern ("barcode"), to which disparity was applied. The stimulus (duration 750ms) was presented at either 20% (L) or 100% (H) contrast in each eye, and all four combinations (HH,LL,LH,HL) were used. We used the high contrast condition (HH) as a reference, and plotted responses to correlated disparity in the other three conditions relative to this. The slope of a type II regression was then used to quantify relative response strength in the other three conditions. Reducing contrast in either or both eyes reduced the strength of disparity selectivity (median ratio 0.83 for LL vs HH, 0.59 for LH and HL vs HH, both significantly different from 1, p=0.03 and < 0.001, sign test). Reducing contrast in one eye only does have a slightly greater effect on disparity tuning compared compared to reducing it in both (median ratio 1.27 for LL vs LH and HL; significantly different from 1, p=0.02), which is qualitatively in agreement with psychophysics. However, the 40% reduction in signal strength for LH and HL relative to HH is larger than the psychophysical effects reported for interocular contrasts in the same range. One explanation for this difference could be that those neurons most affected by interocular contrast differences are given less weight in stereoacuity tasks.

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23.433 **Individual differences: On the possible relativity of spatial-frequency-tuned stereoscopic processes underlying disparity threshold functions** David H Peterzell[1](davidpeterzell@mac.com), Jenny C.A. Read[2], Ignacio Serrano-Pedraza[2,3]; [1]College of Psychology, John F. Kennedy University, [2]Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, UK, [3]Faculty of Psychology. Complutense University of Madrid, Madrid, Spain

To elucidate spatial frequency tuning of stereoscopic mechanisms, two research groups have measured disparity threshold functions, and used factor analytic techniques to estimate the number and tuning underlying stereo channels. One group measured separate thresholds for horizontal and vertical sinusoidal corrugations embedded in dots (0.1 to 1.6 cpd), for thirty observers (Read et al., 2016, JOV; Peterzell et al., 2017, Vision Research). The other obtained thresholds by having participants discriminate between 45° and 135° oblique sinusoidal corrugations embedded in carriers composed of 2-D fractal noise (0.24 to 2.39 cpd), for sixty-one observers (Reynaud & Hess, 2017, Frontiers. Comp. Neurosci.). Both found two significant factors, with rotated loadings tuned to narrow ranges of spatial frequency. However, the factors obtained by the two studies did not match when spatial frequency was classically defined in terms of retinal size, or cycles per degree of visual angle. The differences may reflect differences in methods, different mechanisms, or other procedural differences. However, when the two studies' factors were replotted in cycles per object (where "object" refers to the square aperture containing stimuli for both eyes, hence cycles relative to the object), the high frequency factor from the first study aligned with the low frequency factor from the second. When the results of the two studies are viewed together, using the relative measure of spatial frequency (cycles per object), the two studies may provide evidence for three factors spanning 1-50 cycles. Thus we tentatively hypothesize that cycles per object, rather than cycles per degree, could be the appropriate metric for describing some spatial-frequency-tuned disparity-sensitive processes. These findings lead to the possibility that the spatial frequency tuned mechanisms underlying variability are size-constant mechanisms, similar to those found for, e.g., faces. As these results are preliminary and tentative, additional studies are necessary to address the cycles per object hypothesis.

23.434 **Spatial pooling of local Bayes-optimal estimates predicts human 3D tilt estimation in natural scenes** Seha Kim[1](sehakim@sas.upenn.edu), Johannes Burge[1]; [1]Department of Psychology, University of Pennsylvania

Estimating the three-dimensional structure of surfaces in natural scenes is a fundamental visual task. Previously, we reported that human tilt estimation in natural scenes is tightly predicted by an image-computable Bayes-optimal model grounded in the statistics of natural scenes (Kim & Burge, VSS2017). However, the previous model was limited in two respects: i) it predicted only unsigned tilt estimation (i.e., tilt modulo 180º), and ii) it used only local tilt cues without considering global context. Here, we extend the model to produce signed tilt estimates and to utilize spatial pooling, and we test the predictions of the extended model against newly collected psychophysical data. Each human observer estimated 7200 stereo-image patches that were randomly sampled from natural scenes. Given an image patch, the extended model estimates the Bayes-optimal tilt by computing the mean of the posterior distribution over signed tilt conditioned on the image cue values. The model and human estimates have a similar pattern of bias and variance, and the distributions of model estimates nicely predict the distributions of human estimates for each signed tilt. Next, we found that a simple spatial pooling (i.e., a straight average) of the model's local tilt estimates (i.e., 'global' estimates) provide a better account of the human data than the model's local tilt estimates alone. This result is expected given the spatial correlation of tilt in natural scenes. Taken together, the findings suggest that the human visual system makes the best possible use of image information to estimate local signed

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tilt and spatially integrates local tilts to estimate 3D surface orientation in natural scenes. Future work will develop a Bayes-optimal model of spatial pooling that incorporates the statistics of tilt correlation in natural scenes.

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Scene Perception: Categorization and memory

Saturday, May 19, 8:30 am - 12:30 pm

Poster Session, Pavilion

23.435 Totally-Looks-Like: A Dataset and Benchmark of Semantic Image Similarity

Amir Rosenfeld[1](amir@eecs.yorku.ca), Markus Solbach[1], John K. Tsotsos[1]; [1]Dept. of Electrical Engineering and Computer Science, York University

Human perception of images goes far beyond objects, shapes, textures and contours. Viewing a scene often elicits recollection of other scenes whose global properties or relations resemble the currently observed one. This relies on a rich representation in image space in the brain, entailing scene structure and semantics, as well as a mechanism to use the representation of an observed scene to recollect similar ones from the profusion of those stored in memory. The recent explosion in the performance and applicability of deep-learning models in all fields of computer vision, including image retrieval and comparison, can tempt one to conclude that the representational power of such methods approaches that of humans. We aim to explore this by testing how deep neural networks fare on the challenge of similarity judgement between pairs of images from a new dataset, dubbed “Totally-Looks-Like”. It is based on images from a website in popular media, which hosts pairs of images deemed by users to appear similar to each other, though they often share little common appearance, if judging by low-level visual features. These include pairs of images out of (but not limited to) objects, scenes, patterns, animals, and faces across various modalities (sketch, cartoon, natural images). The website also includes user ratings, showing the level of agreement with the proposed resemblances. The dataset is very diverse and implicitly represents many aspects of human perception of image similarity. We evaluate the performance of several state-of-the-art models on this dataset, comparing their performance with human similarity judgements. The comparison not only forms a benchmark for other similar evaluations, but also reveals specific weaknesses in the strongest of the current systems that point the way for future research.

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23.436 Spatial frequency tuning for outdoor scene categorization

Verena Willenbockel[1,2](willenbockel@psych.uni-frankfurt.de), Sandro Wiesmann[1], Frédéric Gosselin[3], Melissa L.-H. Võ[1]; [1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, Germany, [2]Department of Psychology, University of Victoria, BC, Canada, [3]Département de Psychologie, Université de Montréal, QC, Canada

Which spatial frequencies (SFs) are used for the efficient categorization of real-world scenes? Previous results obtained with the SF Bubbles technique have shown that two SF bands are diagnostic for quick and accurate basic-level categorization of indoor scenes — one around 0.50 cycles per degree of visual angle (cpd) and one around 4.67 cpd (Willenbockel, Gosselin, & Võ, VSS 2017). In the present study, we employed the same technique and paradigm to examine SF tuning for outdoor scene categorization with four natural basic-level categories (coasts, fields, forests, and mountains). The base stimulus set comprised 200 typical gray-scale images per category, all matched in luminance. On each trial, observers saw an image filtered using 20 randomly distributed Gaussian “bubbles”. Stimuli were presented in randomized order and remained on the screen until response. Observers were asked to press the space bar as soon as they recognized the scene category, and upon stimulus offset, press the respective key for the correct category. Performance feedback was provided. Mean accuracy across observers was 91.32% correct (SD = 3.64), and mean RT was 451 ms (SD = 107). A multiple linear regression on the transformed RTs from the space bar press and the respective SF filters revealed a significant SF band around 2 cycles per image (cpi; 0.33 cpd) and another one around 26 cpi (4.33 cpd). When using the transformed RTs from the category key press as regressor, only the high-SF band attained significance (27 cpi; 4.50 cpd). Interestingly, the significant SFs closely match those found for fast indoor scene categorization. Additional second-order analyses on both studies’ data sets indicate that the significant low- and high-SF bands were used conjunctively. Our results show that people rely on a combination of coarse and fine scales for the efficient basic-level categorization of both indoor and outdoor scenes.

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23.437 Identifying Diagnostic Features in Rapid Affective Image Categorization

L. Jack Rhodes[1](LRhodes1@Binghamton.edu), Matthew Ríos[1], Jacob Williams[2], Gonzalo Quinones[1], Prahalada Rao[3], Vladimir Miskovic[1]; [1]Department of Psychology, SUNY Binghamton, [2]Computer Science and Engineering, University of Nebraska-Lincoln, [3]Mechanical and Materials Engineering, University of Nebraska-Lincoln

We assayed the contributions of image Fourier amplitude spectra (AS) and color in two experiments focusing on rapid categorization of affective versus neutral natural scenes. Focusing on the initial feed-forward sweep of activation through the visual hierarchy, we used briefly flashed (~33 ms) scenes that were immediately backward masked with visual textures. Previous studies hint that low-level AS information might guide rapid detection of some image categories (e.g., human faces). In Experiment 1, we used a method developed by Gaspar and Rousselet (2009) to determine whether AS information is used in image categorization, running 3 separate groups: (i) original images, (ii) images with AS information swapped within category and (iii) images with AS swapping between category. A linear support vector machine (SVM) using AS information only was able to discriminate aversive vs. neutral images with ~70% accuracy. Findings from human observers indicate that AS information contributes to affective image categorization only insofar as it destroys image amplitude-phase interactions. In Experiment 2, we focused on the role of color for rapid affective image categorization. Trichromacy provides putative advantages in food detection, detection of social cues in red-skinned conspecifics, enhanced edge and object parsing ability, and enhanced memory encoding and retrieval for some (color-diagnostic) objects. Participants viewed affective and neutral natural scenes either in (i) true color, (ii) red-green (R-G) inverted false color, (iii) blue-yellow (B-Y) inverted false color or (iv) monochromatic viewing conditions. Accuracy findings suggest that false color (particularly R-G inversion) and monochromatic images impaired performance for emotional but not for neutral content, suggesting that chromatic information may help guide affective image categorization.

23.438 Miniature models and immersion: A failed replication

Shane P Baker[1](shane.p.baker@hotmail.com), Matt Moran[1], Derek McClellan[1], D. Alexander Varakin[1]; [1]Psycholgy Department, Eastern Kentucky University

Previous research suggests that viewing movies in realistic miniature theaters can increase feelings of immersion relative to viewing movies on isolated monitors (Baranowski & Hecht, 2014, Perception). The current experiment tested whether realistic miniatures also affect memory for the movie being viewed. Moran et al. (2017, VSS) found that realistic miniature increased immersion relative to unrealistic miniatures, but memory was unaffected. However, the questions used to assess memory were very easy, raising the possibility of a ceiling effect. The current experiment was very similar to Moran et al. (2017). Participants (N = 180) watched the first 11 minutes of a movie (Gulliver’s Travels, 2010) in one of 3 conditions. In the realistic condition, the movie was viewed through a realistic movie theater (complete with patrons and chairs). In the haphazard condition, it was viewed through model with the same dimensions, but materials were haphazardly placed around the walls and floor so as not to resemble a theater. In the no model condition, participants simply watched the movie on a computer monitor. At the end of the clip immersion was measured using Baranowski & Hecht’s questionnaire and memory was assessed with a surprise 20 question multiple-choice test. Ten of the memory questions were used in Moran et al’s experiment, and 10 new questions were added that were intended to be more difficult. Replicating previous

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work, memory was not affected by the different viewing conditions, even though the new questions resulted in lower performance (66% vs. 90%, p < .05). However, immersion results failed to replicate: immersion scores did not significantly differ across the three conditions. Since our method was not identical to Baranowski and Hecht's, it is not clear why our findings differ from theirs. Still, the current results suggest that realistic miniatures may not be sufficient to increase immersion.

23.439 **Concavity and convexity of conjoint surfaces underlie neural and behavioral categorization of scenes and objects** Ruu Harn Cheng[1](rhcannie@gmail.com), Dirk B Walther[2], Soojin Park[3,4]; [1]Emory University, [2]University of Toronto, [3]Yonsei University, [4]Johns Hopkins University

Scene recognition and object recognition are crucial for humans to interact with the world. Places and objects are processed differently and even in anatomically separate brain regions. However, little is known about how the brain triages visual input into the scene versus object processing stream. Places are often characterized by concave boundaries that enclose the local environment, whereas objects are typically encountered as individual entities bounded by convex conjoint surfaces. In this study, we ask whether concavity and convexity of conjoint surfaces might differentiate between scenes and objects. We hypothesize that visual cues of concavity would selectively activate scene-selective processes whereas cues of convexity would selectively activate object-selective processes. In Experiment 1, we created artificial images that vary parametrically in the angle at which two planar surfaces conjoin. There were seven stimulus conditions: three concave, three convex and one flat condition. Planar surfaces in the concave conditions converge in depth, whereas those in the convex conditions diverge in depth. Participants (N=13) viewed stimuli in blocks of 12s while performing a one-back repetition detection task in the fMRI scanner. We measured the univariate response of a scene-selective area (parahippocampal place area; PPA) and an object-selective area (lateral occipital complex; LOC). Consistent with our hypothesis, PPA is sensitive to changes in concavity but not convexity of conjoint surfaces. Conversely, LOC shows an overall greater response to convex than concave conditions. In Experiment 2, we created line drawings of the stimuli from Experiment 1 and asked 100 participants to behaviorally categorize these line drawings as scenes or objects. Consistent with our neural finding, participants categorized line drawings in concave conditions as scenes and those in convex conditions as objects. Together, our results show that concavity and convexity of conjoint surfaces underlie both neural and behavioral categorization of scenes and objects.

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23.440 **Human-Centered Categorization of Natural Scenes** Matt D Anderson[1](ma19g13@soton.ac.uk), Wendy J Adams[1], Erich W Graf[1], Krista A Ehinger[2], James H Elder[2]; [1]Centre for Vision and Cognition, Psychology, University of Southampton, UK, [2]Centre for Vision Research, Department of Psychology, Department of Electrical Engineering & Computer Science, York University, Canada

A scene's categorical identity (e.g. forest or beach) contains useful information, such as the probable identity and location of objects, and the actions that might occur within it. Recent work has provided insights into the computational processes underlying categorization (review: Malcolm, Groen & Baker, 2016). However, most existing category systems are defined by labels selected by small groups of researchers (e.g., Oliva & Torralba, 2001; Fei-Fei & Perona, 2005), or exhaustive vocabularies of place names (e.g., Deng et al., 2009; Xiao, Hays, Ehinger, Oliva, & Torralba, 2010). Here we present a new, psychologically valid method of deriving categories, and report categorization data across three different dimensions for images of natural scenes from the SYNS dataset (Adams et al., 2016). Human observers organised 80 images in a free sorting task. In separate experiments, images were grouped according to (i) semantic content, (ii) 3D spatial structure, or (iii) 2D image appearance. Observers subsequently generated up to 5 text labels to describe each group. Using leave-one-out cross-validation, we determined the most representative category structure for each dimension, and then assigned labels to each category. Inter-observer consistency was highest for semantic categorisation. Our analyses reveal reliable relationships between category dimensions. For example, images in the semantic 'Coast' category were also associated with the 'Flat' 3D spatial structure category, and the 'Blue' 2D appearance category. A Naïve Bayes classifier trained to predict category membership in one dimension from category membership in the other two dimensions performed at around 70% accuracy. This exceeded maximum chance-level performance of 34.17%. These results support scene-centered theories of category representation, which assert that semantic categories can be derived from a limited set of global image properties (e.g., Oliva & Torralba, 2001). The proposed category structures will improve the psychological validity of studies that explore scene categorization.

23.441 **Do Scene-Category Primes Facilitate Scene Perception?** Thomas Sanocki[1](sanocki@usf.edu), Jack Defant[1], Grace MacKay[1], Dana Zipprer[1]; [1]Univ. of South Florida

When observers see several instances of a scene category, the objects and relations and category should be primed, according to mainstream cognitive theories. This priming should then facilitate perception of a new instance of the scene. We tested this idea with the powerful full-report method, which provides rich data about what observers encode from a scene. Observers saw a series of the prime-scenes (1 sec each), followed by a new target scene. The primes were either from the same category as the target (congruent), from a different category (incongruent), or were a neutral sequence. The cognitive prediction is that congruent primes should prime a network for that scene, and should produce more detailed and accurate full reports than the other two prime-types. We tested this prediction in two experiments with differing sets of stimuli; one was standard scenes and one was less typical, creative scenes. Initial analyses indicate that observers reports were detailed and highly accurate in general. However, there was no evidence that prime type influenced the richness of the full reports; word-counts were similar for targets in each of the three priming conditions, in both experiments (23 words/picture). We suggest that category priming effects may be limited to when primes induce observers to prepare a response or interpretation in advance of the target. When the task is more open-ended, as in the present case, there may be no effects of prior semantic and visual information on the efficiency of scene perception.

23.442 **"Scene layout" priming relies primarily on low-level features rather than scene layout** Anna Shafer-Skelton[1](ashafers@ucsd.edu), Timothy F Brady[1]; [1]Psychology, University of California, San Diego

Surprisingly little work has investigated how scene layout information is maintained in memory. One set of studies that has addressed this question uses a scene priming paradigm (e.g., Sanocki & Epstein, 1997), in which different types of previews are presented to participants shortly before they judge which of two regions of a scene is closer in depth to the viewer. Experiments using this paradigm have been widely cited as evidence that scene layout information is stored across brief delays. However, most studies showing this benefit use the scenes themselves or detailed line drawings as previews, with extremely short delays between the preview images and target images. This allows participants' performance to be facilitated by abrupt onsets of the target objects rather than the storage of layout information across the delay. Thus, we sought to examine the extent to which such preview benefits could be due to lower-level visual information held in sensory memory. Using the original (Sanocki & Epstein, 1997) stimuli and timing, we replicated both the photograph and the line drawing preview benefit. However, we also included a manipulation in which the delay between the preview and the target image was lengthened (from 84ms to 200ms) and filled with dynamic visual masks. If the line drawing and photo preview benefits are due to the ability to detect sudden onsets using sensory memory, this manipulation should reduce or abolish the line drawing and photo preview benefits. Indeed, neither preview benefit remained in the masked condition (t's< 1.21 and p's>0.22; N=306), and both effects were significantly decreased relative to the un-masked condition (line drawings: $t(305)=3.04$, $p=0.003$; photos: $t(305)=3.14$, $p=0.002$). These results suggest that scene priming paradigms may primarily pick up on lower-level visual information held in sensory memory rather than scene layout information.

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23.443 Scene Gist Narrative Priming: Sequential expectations influence scene gist recognition performance
Maverick E Smith[1](ms1434@ksu.edu), Lester C Loschky[1]; [1]Kansas State University

What role do scene category expectations play in scene gist recognition? Research has shown viewers accurately identify the gist of briefly flashed scenes presented in randomized sequences suggesting it involves purely feed-forward mechanisms. We investigated if sequential expectations for scenes could influence their gist recognition. We created spatial narrative sequences of images linked along spatio-temporal routes from starting points to destinations (e.g., office, hallway, stairwell, sidewalk, parking lot). 10 scene images from each narrative were presented in an RSVP sequence, with 9 of the 10 images given 300 ms of processing time. The target image was presented for 24 ms simultaneously with an attentional alerting tone and followed by a 48 ms 1/f noise mask. Following presentation of the target and mask, the participant selected the target category from an 8-AFC array of scene category labels. Temporal position of target images within each 10 image sequence was equated and counter-balanced so participants could not guess when the target image would appear. To reduce predictability, we showed 1-3 image subsequences from each category within each narrative so targets were preceded by 0, 1, or 2 images of the same semantic category (e.g., 0, 1, or 2 offices preceded a target office). Scenes were presented in both coherent and randomized sequences to test two competing hypotheses. The "Narrative coherence" hypothesis predicted accuracy would be higher for images in coherent narrative sequences as expectations prime to-be-presented representations. Alternatively, the "Feed-forward" hypothesis predicted accuracy would not differ between coherent and randomized sequences. We found that images presented in coherent sequences were identified more accurately than targets within randomized sequences. Target images preceded by sequential exposures of the same scene category were identified more accurately than targets that were not. Further research will identify whether the facilitation is due to increased sensitivity or bias.

23.444 Evidence for scene gist priming: Seeing a "Cooking" scene facilitates categorization of future "Cooking" actions
Adam M Larson[1](larson@findlay.edu), Karissa B Payne[1]; [1]Department of Psychology, The University of Findlay

In a single eye fixation, people understand the gist of a scene. Scene gist is defined as understanding the general meaning of a scene, which can include objects, actions, and the scene category. Research has shown that scene gist can facilitate object recognition. However, can this facilitative priming effect be transferred to another image? Due to the rapid speed at which scene gist is activated, researchers have theorized that it is the result of a rapid feedforward process, with little, if any, feedback processing. Therefore, each image would generate their own respective feedforward sweep, with little interaction between the two. If so, then understanding scene gist for a picture should not facilitate action categorization of a second image. Conversely, numerous studies have shown that semantically related objects and settings aid identification of those same concepts. This suggests that activating scene gist for one image should prime action categorization in another image. Participants were presented with Prime and Target images that contained semantically congruent or incongruent actions. Their task was to categorize the action in the Target. Various Prime-to-Target SOAs (from 24 to 365 ms) manipulated the strength of the Prime image, while a Target-to-Mask SOA limited target processing time to 24 ms. After the mask, a post-cue appeared that validly cued the target action 50% of the time. The cue remained until participants made a "Yes" vs. "No" decision. A control condition was included where the prime was absent. The data shows that at the earliest prime-to-target SOA, congruent prime images facilitated action categorization. This effect increased until the prime was processed for 100 ms or longer. Conversely, incongruent primes suppressed action categorization. This shows that when various concepts are activated during scene gist, they can prime and speed gist processing for subsequent images.

23.445 Scene gist gets through the bottleneck of visual crowding better than facial expression and orientation
Mingliang Gong[1](gongm2@miamioh.edu), Leonard James Smart[1]; [1]Department of Psychology, Miami University

The gist of a natural scene can be extracted very rapidly (e.g., Rousselet, et al., 2005), without focal attention (Li et al., 2002) and even by pigeons (Kirkpatrick et al., 2014). These findings seem to indicate that the extraction of scene gist is a prioritized process. Consistent with this assumption, one study showed that the gist of a natural scene could be largely extracted when it was crowded in the visual periphery (Gong et al., VSS 2015). However, no study has directly investigated whether the gist of scenes is more readily to extract than other information. Here we employed a visual crowding task to compare the extraction of scene gist (to categorize scene pictures into building, forest, highway and mountain) with the extraction of facial expression (to categorize faces into angry, fear, happy and neutral) and orientation (to discriminate the facing direction of letter "E" into left, right, up and down). In all three tasks, the target, either appeared alone (uncrowded condition) or crowded by two flankers (crowded condition), presented at three eccentricities (9°, 13°, 20°) to the left or right of the fixation for 100 ms. Results showed that the accuracy in the scene gist categorization task was always significantly higher than the accuracies in the other two tasks in the crowded condition, though this was not true in the uncrowded condition. When using accuracy in the uncrowded condition as the baseline to calculate crowding strength, we found that the crowding strength was significantly weaker in the scene gist categorization task than that in the other two tasks at all three eccentricities. These findings indicate that scene gist can better get through the bottleneck of visual crowding and may suggest that the extraction of scene gist is a prioritized process.

23.446 Fifty Years of Rapid Serial Visual Presentation: Is Visual Perception Changing Over Time?
Michelle R Greene[1](mgreene2@bates.edu), Priyanka Takle[1]; [1]Bates College, Program in Neuroscience

Modern life has substantially changed one's visual experience. The average American spends about five hours of time watching TV (Mathews et al., 2008), and the movies and television they are watching have faster cuts and more motion when compared to the content of previous decades (Cutting, 2016). Does viewing more rapid visual content aid performance in laboratory-based visual detection tasks? To answer this question, we examined the nearly fifty years of literature on rapid serial visual presentation (RSVP) of scene images published since 1969. Using Google Scholar, we identified 7,220 studies using RSVP. After limiting the scope to empirical, peer-reviewed papers that displayed RSVP of pictures to human participants and reported behavioral performance on detection or recognition memory, we identified 67 experiments across 23 published studies between 1969 and 2017. Presentation durations ranged from 13-333 ms across experiments. For each study, we identified the task, sample size, display apparatus, and behavioral performance on the most rapid presentation time of the study. When possible, we expressed both detection and recognition measures as d' units. As expected, the across-study performance on visual detection was higher ($d'=1.71$) than that of recognition memory ($d'=1.08$), and that longer presentation times led to higher detection accuracies ($r=0.66$). Over time, RSVP studies tend toward faster visual presentations ($r=-0.42$), and studies have a small but reliable tendency towards smaller sample sizes ($r=-0.36$, $p< 0.005$). Given these factors, we did not observe an overall correlation between detection performance and year ($r=-0.06$, $p=0.64$). When we compared pre-1995 detection studies in the 100-125 ms presentation range to those published since 2007 using the same durations, we found no differences between early ($d'=1.99$) and modern ($d'=2.02$). Therefore, despite large-scale changes in visual experience, we observe remarkably similar scene detection performances that are stable across decade and display apparatus.

23.447 Doing physics by eye and by hand: Mouse tracking reveals reflexive visual processing of physical scenes
Patrick C Little[1](plittle9@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

We can readily appreciate whether a tower of blocks will topple or a stack of dishes will collapse. How? Recent work suggests that such physical properties of scenes are extracted rapidly and efficiently as part of automatic visual processing (Firestone & Scholl, VSS2016, VSS2017). However, physical reasoning can also operate in ways that seemingly differ from visual processing. For example, subjects who are explicitly told that some blocks within a tower are heavier than others can rapidly update their judgments of that tower's stability (Battaglia et al., 2013); by contrast, automatic visual processing is typically resistant to such explicit higher-level influence (Firestone & Scholl, 2016). Here, we resolve this apparent conflict by revealing how distinct flexible and inflexible processes support physical understanding. We showed subjects towers with differently-colored blocks, where one color indicated a 10x-increase in mass. Subjects successfully incorporated this information into their judgments of stability, accurately identifying which towers would stand or fall by moving their cursors to corresponding buttons. However, analyses of these cursor trajectories revealed that some towers were processed differently than others. Specifically, towers that were "stable" but that would have been unstable had the blocks been equally heavy (i.e. towers with unstable geometries) yielded meandering cursor trajectories that drifted toward the incorrect stability judgment ("fall") before eventually arriving at the correct judgment ("stand"). By contrast, towers that were "stable" both in terms of their differentially-heavy blocks and in terms of their superficial geometries produced considerably less drift. In other words, even when subjects accurately understood how a tower would behave given new information about mass, their behaviors revealed an influence of more basic visual (geometric) cues to stability. We suggest that physical scene understanding may not be a single process, but rather one with separable stages: a fast, reflexive, genuinely "perceptual" stage, and a slower, flexible "cognitive" stage.

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23.448 **Alexithymia and the processing of emotional scenes depicting implied motion** Sarah N Rigby[1](umrigby@myumanitoba.ca), Lorna S Jakobson[1], Brenda M Stoesz[1,2]; [1]Department of Psychology, University of Manitoba, [2]The Centre for the Advancement of Teaching and Learning, University of Manitoba

Cognitive alexithymia is associated with impairments in identifying, verbalizing, and analyzing (particularly negative) emotions, which may be rooted in atypical hemispheric laterality and/or stimulus properties. We investigated how alexithymic traits affected processing of emotional scenes using a laterality task in which participants judged the pleasantness of 120 images presented in the presence or absence of a peripheral distractor. Half of the scenes depicted implied motion. Right-handed adults (N = 106) were classified as exhibiting low, moderate, or high levels of cognitive alexithymia using scores from the Toronto Alexithymia Scale – 20 (Parker et al., 2003). Contrary to expectations, no laterality effects were observed. Participants made correct judgments more quickly when a peripheral distractor was presented with the scene, $F(2, 103) = 90.43$, $p < .001$, $\eta p2 = .468$. Participants were also slower at correctly judging negatively valenced scenes, $F(1, 103) = 6.50$, $p = .012$, $\eta p2 = .059$, and those that contained implied motion, $F(1, 103) = 6.04$, $p = .016$, $\eta p2 = .055$, suggesting that these scenes were difficult to process. Accuracy was higher for positive scenes with no implied motion than for other types of scenes, $F(1, 103) = 32.93$, $p < .001$, $\eta p2 = .242$. Finally, participants with low levels of alexithymia showed better accuracy for positive scenes but no effect of implied motion, whereas those with moderate-to-high alexithymia showed the opposite pattern [Group X Motion: $F(2, 103) = 4.03$, $p = .02$, $\eta p2 = .073$; Group X Valence: $F(2, 103) = 3.03$, $p = .05$, $\eta p2 = .056$]. Overall, our results show that stimulus properties, such as implied motion and valence, influence how effectively people with varying levels of cognitive alexithymia process emotional information. These findings provide new insights into the nature of alexithymic deficits and into the functioning of the social brain more generally.

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23.449 **Training expertise in scene recognition** Birken T Noesen[1](noesen.2@wright.edu), Joseph D Borders[1], Assaf Harel[1]; [1]Department of Psychology, Wright State University

Visual analysis of complex real-world scenes is essential to a variety of professional contexts, ranging from defense and intelligence to architecture and urban planning. Expertise in recognizing information-rich yet highly variable scenes is putatively achieved through experience, yet little is currently known about how skills in scene recognition are formed and evolve during learning, and what underlying neural mechanisms support their acquisition. The present study is a first attempt at addressing these questions, quantifying the behavioral changes associated with the acquisition of scene expertise. We assembled a rich stimulus-set consisting of high-resolution color scene images varying across five dimensions: Viewpoint (aerial/terrestrial), Naturalness (manmade/natural), and three hierarchical categorization levels: Basic-level, Subordinate, and Exemplar. For instance, the category "deserts" contained three deserts types (Sandy, Shrub and Rocky), and each desert type contained ten individual images of specific deserts. Critically, each individual scene was presented both in an aerial and terrestrial viewpoint, to assess generalization across viewpoints. We trained 15 participants to categorize these scenes for a total of 12 hours. Each individual training regimen was comprised of six sessions; participants trained on half of the stimuli for five sessions, and in the sixth session they viewed he other half of the scenes. To assess the efficiency of training, we employed two behavioral metrics: (1) within-set learning (i.e. learning across the five sessions), and (2) generalization (i.e. transfer of learning). Learning occurred within the five sessions (evident in a monotonic decrease in reaction times and increase in accuracy), and notably, we also found transfer of learning, as performance in the sixth session was pronouncedly better than performance in the first four training sessions. Together, these results suggest that expertise in scene recognition can be trained in the lab and will form the basis for future studies on the neural substrates of scene expertise.

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23.450 **What sustains viewer interest in a natural scene?** Bhavin Sheth[1, 2](brsheth@uh.edu), King Hei Fung[1], Mariam Ismail[3], Mirza Baig[4]; [1]Electrical & Computer Engineering, University of Houston, [2]Center for Neuroengineering and Cognitive Science, University of Houston, [3]Mechanical Engineering, University of Houston, [4]University of Houston

Gauging the interest level of a person viewing a scene is potentially useful to the study of human behavior. While we know a lot about what attracts interest in an individual, e.gs. abrupt onsets, visual pop-outs, semantically incongruous scenes, we know less about what sustains interest. Here, we address this question in two sets of studies. In the first study, we measured interest sustainment to scenes of the same semantic category. Specifically, subjects viewed a series of scenes while we measured their viewing time, tracked their eyes, and asked them to rate their interest in the scene. In six separate sessions on separate days, subjects (n=17) viewed a series of 25 scenes of the same general category (aerials/cityscapes/indoors/landscapes/people, and a combined mix) in a self-paced manner. Subjects spent significantly longer time viewing landscapes than cityscapes, indoors, people, or the combined mix. Viewing time declined with trial number as expected but the longer mean viewing times on landscapes remained. The number of saccades/fixations the subject made while viewing the scene correlated significantly with viewing time, whereas saccade and fixation durations did not. A second experiment on new subjects (n=48) with new (75/category) scenes confirmed overall significantly longer viewing times on landscapes versus people; subjective interest ratings (landscapes>combined>people) aligned with viewing times. In the second study, we present two scenes from different categories side by side and compare the time subjects spend viewing one scene versus another and ask subjects to provide a subjective interest rating for each of the scenes in the pair. The study is ongoing. In both studies, we correlate viewing time and interest rating with measures of image complexity based on fractal dimension and Jansen-Shannon divergence in order to test the hypothesis that the complexity of a natural scene is a good proxy for sustained interest.

23.451 **Dynamics of aesthetic experience are reflected in the default-mode network** Edward A Vessel[1](ed.vessel@ae.mpg.de), Amy Belfi[2], Aenne Brielmann[2], Ilkay Isik[1], Anjan Chatterjee[3], Helmut Leder[4], Denis G. Pelli[2], G. G. Starr[5]; [1]Neuroscience, Max Planck Institute of Empirical Aesthetics, [2]Psychology, New York University, [3]Neurology, U. Pennsylvania School of Medicine, [4]Basic Psychological Research and Research Methods, U. Vienna, [5]English, Pomona College

Aesthetic experience with static visual art engages visual, reward and default-mode (DMN) networks, yet very little is known about the temporal dynamics of these networks during aesthetic appreciation. Previous behavioral and brain imaging research suggests that critical aspects of aesthetic experience have slow dynamics, taking more than a few seconds, making them amenable to study with fMRI. Here, we identified key aspects of the dynamics of aesthetic experience while viewing art for various durations (1, 5 or 15 s). Thirty observers continuously rated the pleasure they experienced both during image presentation and during a 14 s post-stimulus period, followed by an overall judgment of an image's aesthetic appeal. Overall judgments were used to sort trials into high, medium, and low aesthetic appeal. In the first few seconds following image onset, activity in the DMN (and high-level visual and reward regions) was greater for high appeal images; in the DMN this activity counteracted a suppressive effect that grew longer and deeper with increasing image duration. In addition, for high appeal art, the DMN response returned to baseline in a manner time-locked to image offset. Conversely, for non- appealing art, the timing of this return to baseline was inconsistent. This differential response in the DMN may therefore reflect the internal dynamics of the observer's state: the observer disengages from art-related processing and returns to stimulus-independent thought in a manner that is dependent on subjective aesthetic appeal. These dynamics suggest that the DMN tracks the internal state of an observer during aesthetic experience.

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23.452 **From pixels to moral judgment: Extracting morally relevant information in minds and machines** Julian De Freitas[1](defreitas@g.harvard.edu), Alon Hafri[2], Daniel LK Yamins[3], George A Alvarez[1]; [1]Psychology, Harvard University, [2]Psychology, University of Pennsylvania, [3]Psychology, Stanford University

How does the mind extract morally relevant information from visual scenes? We present evidence that humans can make reliable moral judgments based on information presented in the blink of an eye: after viewers see briefly presented static scenes of two people interacting, they can correctly identify (i) who acted on whom (i.e., event role) and (ii) whether the observed event was harmful, and (iii) they can make a reliable moral wrongness judgment about a specific individual in the social interaction. Next, we find that a deep convolutional neural network model trained only to recognize objects can be used to produce moral judgments that are almost indistinguishable from those of humans, with only minimal additional training: a linear transform from its high-level features to the role, harm, and moral labels. We also find that earlier representational layers of this network can accurately predict role, but only later layers can predict harm and moral wrongness. Furthermore, this model shows patterns similar to human behavior (i) at the individual-scene level, and (ii) when confronted with a separate set of experimentally manipulated images for which it is more difficult for humans to identify who acted on whom. Based on these results, we argue that in the process of learning to recognize objects, the visual system also learns high-level visual features that can be used to make reliable moral judgments about observed events.

23.453 **The Influence of Environmental Features on Egocentric Distance Judgments in Virtual Rendered Scenes** Lindsay Houck[1](lindsayhouck@gwmail.gwu.edu), John Philbeck[1]; [1]The George Washington University

Objects are judged up to 8m farther in wide (40m) versus narrow (1.5m) rooms (for targets rendered at a distance of 37m; VSS 2017). These large effects emerge at relatively far distances, where the role of visual cues is poorly understood. The multiplicity of possible factors makes determining the cue bases a challenge. Here, we used rendered scenes and Amazon's Mechanical Turk to test several candidate hypotheses. Stimuli were empty 40m-deep rooms lined with irregularly-placed doors and an orange cone 4–37 m from the observer's viewpoint. 95 MTurk workers numerically judged the cone distance. We tested the role of linear perspective (by adding black lines to floor and ceiling in 40m-wide rooms), visibility of the near and far ground plane texture (by introducing transverse walls and hallway openings), and visibility of a larger outer environment (by removing walls from a 1.5m-wide hallway but leaving freestanding doors). We also included 40m-wide rooms and 1.5m-wide hallways. Results showed main effects of scene and distance, and a scene x distance interaction (all ps $< .0001$). Judgments for the 40m width and 40m width + linear perspective scenes were similar to each other ($p>.05$), and larger than in the other four scenes (by up to 8.7m for the 37m target distance). Judgments in the other four scenes did not differ from each other (all ps$>.05$). The results did not identify a single visual feature that drives the difference in judgments across room widths, although they did constrain the possibilities. Most interestingly, large occlusions of the near versus far ground plane yielded statistically indistinguishable judgments, and neither gave rise to the larger judgments associated with wide rooms. Some remaining possibilities for the effect of room width on distance judgments include total amount of visible ground texture and presence of boundaries or barriers to navigation.

Faces: Recognition and perception

Saturday, May 19, 8:30 am - 12:30 pm

Poster Session, Pavilion

23.454 **The face-number effect: a new test of face discrimination** Sarra Djouab[1,2](sarra.djouab@gmail.com), Shanna Yeung[1], Andrea Albonico[1], Sherysse Corrow[1], Jason JS Barton [1]; [1]Human Vision and Eye Movement Laboratory, Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, Psychology, University of British Columbia, Vancouver, Canada, [2]Faculty of Medicine, University of Auvergne, Clermont-Ferrand, France

Background: The recent many-to-many hypothesis claims that faces and words share for neural resources, leading to studies comparing face and visual word recognition. However, one difficulty of these studies is that the tests used to assess face and visual word processing and diagnose alexia and prosopagnosia differ in their measures. The key feature of alexia is an elevated word-length effect, while the diagnosis of prosopagnosia rests upon reduced accuracy on face recognition tests. Objective: Our goal was to develop an assessment of face discrimination that a) had response time as the outcome variable, and b)indexed the perceptual processing load. Method: We created two tests, in which subjects made a same/different judgment with an array of faces that could vary in the number of faces shown. In the first test, each trial showed a display of faces that varied slightly in expression. On half the trials all the faces were from the same individual, while on half, one of the faces was of a different person. In the second test, the expressions were either all the same or differed in one face. Accuracy and response times were measured. Results: Accuracy was similar in both healthy and prosopagnosic subjects. The time needed to respond correlated with the number of faces in the array. Thus, we defined the 'face number effect' as the slope of the linear regression between the number of faces and the response time. For identity, this was about 200 ms/face in healthy subjects, and 600 ms/face in prosopagnosic subjects. For expression, the face-number effect was about 170ms/face, and slightly increased at a mean of 375ms/face in prosopagnosic subjects. Conclusion: The face-number effect can reveal a reduced perceptual capacity for processing face identity and may provide a parallel to the word-length effect, in assessing processing as a function of perceptual load.

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23.455 **Understanding Information Processing Mechanisms for Face Categorizations in Deep Neural Networks** Oliver G B Garrod[1](oliver.garrod@glasgow.ac.uk), Tian Xu[1], Philippe G Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, Scotland, UK

Deep neural networks (DNN) perform well for identifying faces from diverse sets of images. However, the details of the processing within such networks as they perform invariant face categorizations remains unclear. Here we study the development of categorical representations across layers of a DNN trained to categorize facial identity. We generated a data set of 26,250,000 face images using a photorealistic 3d generative model, comprising 2,000 unique facial identities (balanced across gender and two ethnicities) visualized with different ages and emotional expressions, and across multiple orientations, illuminations, scalings and translations. We trained a 10-layer ResNet with 70% of these images to recognize the 2000 individual identities. We tested with 10,000 images (not used for training) and obtained 99% correct identification. To understand how categorization develops within the network we computed, for each layer, a 10,000 x 10,000 Representational Dissimilarity Matrix (RDM) from the correlation between network activations for each pair of testing images. We then compared the RDM derived at each layer with the discrete categorical

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RDM model for each of the main category factors entering stimulus generation. We found the early layers of the network most strongly represent orientation of the face, together with ethnicity. In later layers, invariance to orientation develops, and representation of the identity factors gender, ethnicity and age increase. No layers show a strong representation of illumination. Prior to identity readout in layer 10, ethnicity is the most strongly represented category, with representation peaking in the middle layers (5,6,7) before decreasing in the upper-most layers. By tightly controlling the categorical sources of variance of an image set used to train a DNN, we can derive an understanding of the implicit categorizations that it can achieve at each layer. Our results also shed light on the computational complexity of different facial categorizations.

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23.456 **Face recognition in humans and machines** Naphtali Abudarham[1](naphtool@gmail.com), Lior Shkiller[1], Galit Yovel[1,2]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

Deep neural networks (DNNs) have recently reached the level of human face recognition in unconstrained settings. Most studies that compared human and machine recognition so far have focused on overall performance level. Yet, little is known about the nature of the face representation generated by humans and machines. In the current study, we compared human and machine similarity ratings on faces in which we systematically changed different features. In previous studies, we found that features for which humans show high perceptual sensitivity (PS) for detecting differences between them are more important for face recognition than features for which humans have low perceptual sensitivity. We also found that these high-PS features tend to vary less across appearance variations, making them more useful for recognition under changing conditions.
In this study, faces were manipulated such that they differed in either high-PS or low-PS features, and we measured the distance scores between original and changed faces using a DNN algorithm (learned features), a traditional LBP algorithm (engineered features), and human similarity scores. We found that both DNNs and humans rated faces that differed in high-PS features as more dissimilar than faces that differed in low-PS features, whereas for the engineered-feature algorithm, similarity ratings were similar for both types of changes. Taken together, our findings suggest that DNNs, which are trained on unconstrained images, produce an internal face representation that is similar to that of humans, relying on a subset of facial features for recognition that are invariant across different appearances of the same individual, whereas the engineered-feature algorithm assigns more evenly distributed weights to all the information in the face. We conclude that training with unconstrained faces, in humans and DNNs, biases the representation of faces to a similar subset of facial features that support face recognition across different appearances.

23.457 **Testing the limits of identity recognition with mixed-identity faces** Isabelle Buelthoff[1](isabelle.buelthoff@tuebingen.mpg.de), Mintao Zhao[1,2]; [1]Max Planck Institute for Biological Cybernetics, Human Perception, Cognition and Action, [2]University of East Anglia

Similarly to how we look for telltale signs of both parents' facial features in their children's faces, we are able to recognize two identities from one photo that mixes two persons' faces together. When more people's faces are used to create mixed faces, the identities of individual faces (i.e., "parent" faces) become less recognizable (i.e., identity information is degraded). In our study, we investigated the limit of identity recognition in such identity-degraded faces and whether familiarity with the "parent" faces enhances identity recognition from such mixed faces. We first tested whether people can extract the identities from a mix of three faces. Participants who were familiar with the "parent" faces performed better than those who were not. We then tested whether participants can extract the identities of mixed faces generated with more faces. We showed a mixed face of 2 to 10 "parent" faces together with a test face. Participants had to decide whether the test face was a parent of the mixed face. Both familiar and unfamiliar participants performed better than chance for mixed faces generated with up to eight faces. Finally, we tested at what level mixed faces lose their identity so that we cannot discern between two mixed faces generated with completely different "parent" faces. We presented two mixed faces in a trial and participants performed a same/different task. Both mixed faces had the same number of identities (2 to 32), but had no parents in common. Participants were better than chance even for the 32-face mixed faces. Together, these results indicate that our face processing system is extremely sensitive to facial identity information. Familiarity helps identity recognition, but this advantage becomes less evident when identity information degrades (i.e., with increased number of "parent" faces in a mixed face).

23.458 **How Many Faces Can We Recognize?** Emily X Meschke[1](emeschke@usc.edu), Catrina M Hacker[2], Irving Biederman[2,3]; [1]Computational Neuroscience, University of Southern California, [2]Neuroscience, University of Southern California, [3]Psychology, University of Southern California

How many faces can a person recognize? We consider three classes of relations where we have an opportunity to learn a person's face: a) celebrities (e.g., entertainers, athletes, politicians, rogues) with which we have no personal contact, b) individuals with whom we have personal contact such as friends, frequent service people (e.g., physicians, instructors), classmates, coworkers, and family, many of whom we can name and cite biographical details, and c) people we know from a specific context, such as a barista or a passenger on our usual bus route, for whom we know only from that context, rarely by name or biographical detail. To assess celebrity recognition, participants were presented with a pair of faces and asked to judge which one is famous. One was a headshot of a celebrity sampled at various degrees of fame (US Weekly Estimate) and the other a non-celebrity doppelganger of the celebrity (Fig. 1). The integral of the accuracy function over citation frequency can provide an estimate of the first class (recognizable celebrities) (Fig. 2a). The second class (personally familiar), will be estimated from the number of Facebook friends that the subject confirms are recognizable plus the cumulative number of names or identifying descriptions generated over a two-week period, excluding those already accounted for from Facebook (Fig. 2b). The third (contextually familiar) will be estimated from logs that participants will be asked to keep for two weeks in which they mark the number of familiar faces that they encounter each day without knowing the names of those individuals. The asymptote of the number of unique individuals encountered will be the estimate predicted from the two-week sampling (Fig. 2c). The sum of the three estimates will provide, for the first time, a lower-bounds estimate of the number of identifiable faces.

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23.459 **Faces as spectra: implications for adaptation and face coding** Alexandra K Aniban[1](anibxn@nevada.unr.edu), Kara J Emery[2], Courtney Matera[2], Michael A Webster[1,2]; [1]Department of Psychology, University of Nevada, Reno, Reno, NV 89557, [2]Graduate Program in Integrative Neuroscience, University of Nevada, Reno, Reno, NV 89557

Studies of face coding have used adaptation to examine whether a facial dimension (e.g. gender or age) is represented by many narrowly tuned mechanisms or a small number of broadly tuned mechanisms. However, these models typically treat variations in the face as unique points along the coding dimension. Many natural stimuli instead correspond to a distribution of values (e.g. light spectra for color or amplitude spectra for space) rather than a punctate level (e.g. a single wavelength or spatial frequency). We examined the implications of reconceiving the face as a distributed spectrum for interpreting neural codes from face aftereffects. As a proof of concept, facial variations were created as the sum of local distortions at either different spatial locations (along the height of the face) or at different spatial scales (corresponding to different spatial frequencies of distortions). For modest distortions these appeared as plausible variations in real faces. Adaptation to the distorted faces produced strong aftereffects in the appearance of the original face. For example, adapting to a face that was contracted around the mouth and expanded around the eyes caused the original face to appear biased in the opposite way. These aftereffects are expected given the similar patterns of adaptation observed for face stimuli defined by functionally equivalent global distortions. However, the implications of the aftereffects are very different, because the implied channel structure depends on the assumptions about the stimulus structure. In particular, adaptation to the broadband face spectrum is predicted to produce broad and global changes in the channel responses even when the channel bandwidths are narrow, and predicts a normalization pattern of aftereffects even when there are many channels spanning the dimension. Our analysis illustrates important limits on the inferences that can be made about the neural representation of faces from how that representation adapts.

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23.460 **Recognition of Stretched Faces** Catrina M Hacker[1](chacker@usc.edu), Emily X Meschke[2], Irving Biederman[1,3]; [1]Neuroscience, University of Southern California, [2]Computational Neuroscience, University of Southern California, [3]Psychology, University of Southern California

In 2002, Graham Hole showed that, somewhat remarkably, vertically stretching a face by a factor of two (Fig. 1) had only a minimal effect on its recognition, as assessed by judgments of whether the face was that of a celebrity. This is surprising given that such stretching produces a marked change in the magnitude of the relations between the parts as well as on the shape of the parts and the head. Subjects viewed grayscale images of celebrities and non-celebrities either not stretched or stretched vertically by a factor of 2 (2x) or 4 (4x) and judged whether the face was famous or not. We confirmed Hole's results showing no effect of stretch on either RTs or error rates, but extended the evidence for invariance out to 4x stretch. Subjects varied in their familiarity with particular celebrities allowing a test of the possibility that the invariance to stretch was a consequence of having viewed familiar celebrities at various orientations in depth, perhaps producing familiarity with affine transformations of that face. This hypothesis was not supported in that there was no interaction between degree of stretch and the subject's familiarity with a given face. An alternative hypothesis is that humans have a general capacity for affine transformations of faces, independent of familiarity.

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23.461 **Blurry faces are easier to recognize when viewed small** Ipek Oruc[1](ipor@mail.ubc.ca), Morteza Mousavi[1,2]; [1]Ophthalmology and Visual Sciences, UBC, [2]Graduate Program in Neuroscience, UBC

Critical spatial frequencies (SF) that enable visual object identification change with stimulus size (Majaj et al., 2002; Oruc & Barton, 2010). Observers utilize coarse features at small sizes and fine details at large sizes. Faces viewed at small sizes around 2° width are recognized using SFs around 3-4 cycles/face-width—a scale too coarse to resolve individual facial features. In contrast, faces larger than 5° in width are recognized using SFs around 8 cycles/face-width. However, it is unclear whether these results, which are due to subthreshold viewing of noisy images, are relevant to suprathreshold recognition of familiar faces. We employed a celebrity-naming procedure to examine this question. Observers (N=19) were asked to name 100 celebrity faces in a random order. Each face was viewed in one of four conditions based on size (small=2° vs. large=10°) and resolution (intact vs. blurry). Blurry faces were generated by low-pass filtering the images at 6 cycles/face-width. Faces were randomly assigned to each condition for each individual observer and viewed in a random order. Faces that were unfamiliar to the observers (determined in post-test debriefing) were excluded from the analysis. A repeated-measures ANOVA showed a significant main effect of size ($F(1, 18)=17.11$, $p< 0.001$) and resolution ($F(1,18)=44.17$, $p< 0.001$) as well as a significant interaction between the two ($F(1,18)=17.36$, $p< 0.001$). Intact faces were named with near 100% accuracy at both sizes. Accuracy for blurry faces was 84% at the small size, which was significantly greater than the 73% accuracy at the large size. Blurry face-naming accuracy was greater at the small size compared to large for 15 of the 19 observers. These results have implications for approaches to visual aids for low-vision. Specifically, they suggest that magnification may not be an appropriate option for improving face recognition.

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23.462 **The effects of blur and inversion on sorting ambient face images by identity** Hannah I Pearson[1](hannah.i.pearson@ndsu.edu), Jacob Gable[1], Benjamin Balas[1]; [1]Psychology Department, North Dakota State University

When presented with unfamiliar faces that vary in expressions, angles, and image quality, observers exhibit high rates of recognition errors (Jenkins et al., 2011). Specifically, in unconstrained identity-sorting tasks, observers generally struggle to "tell people together" (cope with variation across different images of the same person) while being able to successfully "tell people apart" (distinguish between images depicting two different people; Andrews et al., 2015). The use of ambient, noisy face images in this simple card sorting task both reveals the magnitude of these face recognition errors, and suggests a useful platform to re-examine the nature of face processing using naturalistic stimuli. Currently, we used this task to assess the impact of two stimulus properties (image blur and orientation) known to affect face recognition in tasks using controlled stimuli, but which may have a different impact when applied to ambient face images. In Experiment 1 (Image Blur), we recruited 64 participants who sorted highly-variable images of unfamiliar female faces subject to low (N=22), medium (N=21), or high levels of blur (N=21). In Experiment 2 (Picture-plane Inversion), we recruited 35 participants who sorted either upright (N=17) or inverted (N=18) images. We analyzed the sorting solutions from both tasks using signal-detection descriptors (Balas & Pearson, 2017) that allow us to characterize card grouping in terms of sensitivity to extra-personal variability and response bias. We found that in Experiment 1, the level of image blur did not modulate performance, affecting neither observers' d' values ($F(2,61)=1.51$, $p=0.23$) nor their response criterion ($F(2,61)=1.82$, $p=0.17$). In Experiment 2, however, we found that picture-plane inversion led to significantly poorer sorting performance than the upright condition ($t(33)=2.91$, $p=0.0065$) but no change in the response criterion ($t(33)=-1.52$, $p=0.14$). Unconstrained, ambient face identity sorting is thus resilient even to substantial levels of image blur, but suffers greatly from face inversion.

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23.463 **Inversion leads to qualitative changes in face processing but not in word processing** Andrea Albonico[1](nea.albonico@gmail.com), Amanda Furubacke [1,2], Jason JS Barton[1], Ipek Orc[3]; [1]Human Vision and Eye Movement Laboratory, Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, Psychology, University of British Columbia, Vancouver, Canada, [2]Faculty of Medicine, Linköping University, Linköping, Sweden, [3]Department of Ophthalmology and Visual Sciences, University of British Columbia

Face and visual word recognition are two prime examples of expert visual processing in humans. Both activate the fusiform gyrus, a key region in visual expertise, and show an inversion effect - a marked reduction in performance when stimuli are turned upside down - which is attributed to an orientation-dependent expertise because our experience with these stimuli is biased towards the upright orientation. Here, we investigated inversion effects on two invariant aspects of visual performance, efficiency and equivalent input noise. We hypothesized that visual objects like faces and words, for which we have developed expertise, would show significant gains in efficiency and/or reductions in noise when stimuli were seen upright rather than inverted, and that this effect would be greater than that for an object type (e.g., houses) for which we are not expert. Twelve subjects performed five-alternative forced-choice tasks, in which we measured identification contrast thresholds for three stimulus categories (faces, words, houses) in two orientations (upright, inverted) under two noise conditions (no-noise, white noise). Efficiency was calculated relative to an ideal observer. We found that efficiency was greater for visual words than faces, and reduced for houses compared to words and faces. Inversion profoundly reduced efficiency for faces, while it had only a modest effect on efficiency for visual words and houses. Equivalent input noise was slightly higher for faces than for visual words, but was not affected by inversion for any stimulus. These results show that even though face and word recognition are both expert processes with known inversion effects, this orientation-dependent expertise differs in its impact on efficiency. While one of the orientation-specific gains in face processing is enhanced efficiency, this is not the case for visual words, suggesting that there is a different origin for the inversion effects reported for visual word processing.

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23.464 **A strong bias to fixate the upper eye in tilted faces** Nicolas Davidenko[1](ndaviden@ucsc.edu), Hema Kopalle[1], Bruce Bridgeman[1]; [1]Department of Psychology, University of California Santa Cruz

There is a well-known left-gaze bias when looking at faces: the left side of the face (from the point of view of the observer) receives more first fixations and has a greater influence on perceptual decisions than the right side of the face (Campbell, 1978; Guo et al., 2009). Here we investigated whether the in-plane orientation of a face image influences the left-gaze bias. In Experiment 1, we developed an expression classification task that elicited a strong left-gaze bias in upright faces, regardless of whether face images had been mirror-reversed (ruling out stimulus effects). In Experiment 2, a new group of participants completed the same task on faces that were presented either upright, rotated clockwise by 45°, or counterclockwise by 45°, while their eye movements were being tracked. We predicted that in addition to a left-gaze bias to upright faces, participants might show an upper eye bias to tilted faces, manifesting as more first fixations to the left eye of clockwise-rotated faces, but more first fixations to the right eye of counterclockwise-rotated faces. Our findings confirmed this prediction; in fact, the tendency to fixate the upper eye in rotated faces completely dominated any lateral bias (Figure 1A). In Experiment 2, we tested additional orientations (0°, ±11.25°, ±22.5°, ±33.75°, ±45°, ±90°, and 180°) to determine at what angle this upper-eye bias overrides the left-gaze bias. To our surprise, even a small counterclockwise tilt of 11.25° was sufficient to eliminate the left-gaze bias, with the upper eye bias peaking for ±45° faces (Figure 1B). We consider a potential mechanism for this upper eye bias in light of recent findings (de Haas et al., 2016) showing that cortical responses to facial features are enhanced when features appear in canonical positions relative to fixation.

23.465 **Is Body Size Estimation Viewpoint Invariant?** Anne Thaler[1,2,3](anne.thaler@tuebingen.mpg.de), Isabelle Bülthoff[1], Sergi Pujades[2], Michael J. Black[2], Betty J. Mohler[2,4]; [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]Technical University Darmstadt

Previous research on own body size estimation has only looked at estimates made by comparing own body size to a test body in front view (e.g., Mölbert et al. 2017). However, people constantly see and compare themselves to bodies in different viewpoints. Depending on the viewpoint, shape cues potentially used to judge body size, such as the waist-to-hip ratio or the overall body outline, vary. Here, we asked whether viewpoint influences estimates of own body size in female participants. For each participant, a personalized female avatar was generated using weight, height, inseam, and arm span, and then variations of the personalized avatar having different weights (±5%, ±10%, ±15%, ±20%, and ±25%) were created using a statistical body model. These eleven test bodies were presented in life-size in immersive virtual reality in six viewpoints: 0°, ±45°, ±90°, 180°. In a one-alternative forced choice paradigm, participants were asked to judge whether the test body was thinner or fatter than themselves. Results showed no significant influence of viewpoint on either the accuracy of body size estimation (PSE) or the sensitivity to weight changes (JND). Across all viewpoints, participants on average slightly overestimated their body weight (3.1%) and could detect a weight difference of 5.2% in 50% of the trials. To further investigate whether females are also able to estimate own body size when the shape of the test bodies is clearly different to theirs, a set of personalized male avatars was generated for each participant and presented in front view using the same task. There was no difference in results between female and male test bodies. These results suggest that people are rather good at extracting body size independent of the viewpoint, and also from bodies with a very different shape.

23.466 **Holistic gist: The speed of holistic face processing** James W Tanaka[1](jtanaka@uvic.ca), Buyun Xu[1]; [1]Department of Psychology, University of Victoria, Victoria BC

In scene perception, there is evidence that the observers are able to extract the "gist" (i.e., semantics) from images presented as briefly as 13 ms (Potter et al., 2014). Although it is well known that faces are perceived holistically, how the holistic face gist is encoded has not been extensively explored. To test for the presence of gist processing, in Experiment 1, we flashed a study face for either 17, 50, 250 or 500 ms, followed by a 500 ms dynamic white-noise mask. Recognition of face features (eyes, nose, mouth) was then tested in isolation or in the whole face using Tanaka and Farah's parts/wholes paradigm (Tanaka & Farah, 1991). We found that eyes were better recognized in the whole face than in isolation when presented at an exposure duration of 17ms and mouth was better recognized in the whole face when presented for 50 ms and 250 ms. In Experiment 2, participants were asked to recognize the eyes and mouth in upright and inverted faces presented at 17, 50 and 250 ms using the same parts/whole paradigm as Experiment 1. The main effect of orientation was found where recognition in the inverted condition was significantly worse than the upright condition. Moreover, a significant Parts/Whole by Orientation interaction effect was found where recognition of features was better in the whole face than in isolation when faces were upright, but not when faces were inverted. Importantly, for upright faces, at 17 ms exposure duration, eyes were better recognized in the whole face than in isolation. For inverted faces, no differences were found between the whole face and isolation conditions. Collectively, these results present the striking evidence that the in face processing, holistic gist can be encoded at an exposure duration as short as 17ms.

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23.467 **The Impact of Viewing Time to Internal Facial Features on Face Recognition Performance Following Implicit and Explicit Encoding** Karisa B Parkington[1](kparkington@uwaterloo.ca), Roxane J Itier[1]; [1]Department of Psychology, University of Waterloo

The eyes play an important role in conveying social cues, including identity. Previous studies have shown that face recognition performance is higher when the eyes are visible or cued during encoding, compared to when the eyes are absent or when other features are cued. Here we explored the relationship between time spent looking at the eyes during encoding and face recognition performance, and whether this link might vary with task demands. Eye movements were compared while participants mentally assessed the trustworthiness of faces (implicit encoding task), and when they memorized the identity of faces (explicit encoding task). Behavioural performance was obtained during a surprise old/new face recognition test following the implicit task, and during an expected old/new face recognition test following the explicit task. With a preliminary sample (N = 38), participants spent less time looking at the mouth during encoding, compared to the left eye, right eye, and nose, which did not differ from each other. However, task demands did not differentially affect feature viewing times. Face recognition accuracy (d') was higher following the explicit encoding task compared to accuracy following the implicit encoding task. Moreover, for the explicit task only, longer viewing time to the left eye was weakly associated with higher accuracy, whereas longer viewing time on the nose was weakly associated with lower accuracy. These findings support a link between time spent looking at specific facial features and face recognition performance that seems dependent on the task demands at encoding, such that only the left eye seems to play a role in facilitating intentional face recognition.

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23.468 **Looking at faces is differentially modulated by context and novelty** Effie J 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

Past studies have shown that humans preferentially and spontaneously look at social cues like faces and eyes. Here, we investigated the role of context and face novelty in this effect. Participants viewed displays depicting a face and house stimuli within their natural context, equated for size, distance from fixation, and other low-level visual properties. Each stimulus could be positioned on the left or right of fixation and presented in an upright or inverted orientation. After 250ms, the display offset, and participants were asked to identify a target occurring at the previous location of the face (eyes or mouth) or the house (top or bottom). All cue-target combinations were equally probable. To measure natural oculomotor behavior, participants were not instructed to maintain fixation and their eye movements were recorded using an eye tracker. We examined saccades launched from fixation towards one of the regions of interest

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(Eyes, Mouth, House top, House bottom) during the 250ms cue display. In Experiment 1, a single face and house display was presented. In Experiment 2, thirty-two different face-house pairs were used within the same task. In Experiment 1, a greater proportion of saccades were directed towards the eyes and mouth relative to the house, with larger effects for upright faces and faces presented in the left visual field. In Experiment 2, a greater proportion of saccades were directed toward the eyes relative to the mouth and the house, with no differential effects for cue orientation or face position. Together, these findings suggest that oculomotor biasing towards social cues is differentially affected by social context relative to stimulus novelty.

Acknowledgement: NSERC NSERC- CREATE SSHRC William Dawson

23.469 **Human faces capture attention and attract first saccades without longer dwell times** M.D. Rutherford[1](rutherm@mcmaster.ca), Marcus Morrisey[1], Ruth Hofrichter [1]; [1]Psychology, Neuroscience & Behaviour, McMaster University

Introduction: Human faces attract attention, evidenced by reaction time (RT) advantages over non-face stimuli in visual search tasks (Downing, Bray, Rogers, & Childs, 2004; Ro, Friggel, & Lavie, 2007). Method: On each trial, participants were cued with one of 6 possible categories names (automobiles, birds, chairs, dogs, faces, or plants). A circular array of 6 images, one exemplar from each category, was then presented. Participants' task was to indicated whether the target in the green frame did or did not match the cue. Foil images were framed in blue. Participants' eye movements were tracked during the search task to test how the attentional capture of faces is related to looking behavior, including dwell time and saccadic eye-movement. Results: Faces as targets resulted in faster search times (Wald X2 = 13.1, p = .02), which is consistent with previous research (Ro, Friggel & Lavie, 2007). Faces were more likely to capture first fixations (Wald X2 = 57.2, p = .02) regardless of whether they were the target. Faces exhibited shorter dwell times compared to other categories (Wald X2 = 140.2, p = .001), again regardless of whether they were the target image. Discussion: Faces effectively captured attention, attracting first fixations, and were fixated for shorter durations. Thus, participants appeared to be more fluent at processing faces, resulting in ultra-rapid face processing. These results suggest that RT advantages for faces are due to both attention capture and ultra-rapid processing.

23.470 **Independent mechanisms for ensemble processing of face viewpoint and identity** Marco A Sama[1](marco.sama@mail.utoronto.ca), Adrian Nestor[1], Jonathan S Cant[1]; [1]Department of Psychology, University of Toronto Scarborough

Ensemble processing refers to the visual system's ability to process features from large collections of stimuli in a scene (i.e., an ensemble) by statistically compressing redundant information (e.g., computing the average size of a set of shapes). Typically, participants are more accurate at reporting the average feature of a set compared with any individual feature. Here, we investigated ensemble face-processing mechanisms for higher-level identity and lower-level viewpoint features. To this end, in four different experiments we examined single and average feature extraction from face ensembles that varied continuously in identity and/or viewpoint. Specifically, participants reported either the average feature of a set or that of a single face, randomly selected from an ensemble of six unfamiliar faces. Our findings indicate, first, that participants were more accurate at reporting viewpoint than identity, consistent with different levels of processing for the two types of features. Second, we found that average face reports were generally more precise than single face reports and that single face reports were biased towards the average of the set especially under increased cognitive load. Third, surprisingly, the average viewpoint of an ensemble, varying between -60 and 60 degrees relative to a frontal view, did not influence the precision of identity reports for either average or single faces. Finally, estimates of average identity and viewpoint were both precise regardless of whether they were reported simultaneously or separately, with no interference from the irrelevant feature. Thus, the present findings point to distinct levels of ensemble processing operating on viewpoint and identity information. More generally, these results argue for the existence of multiple, robust and independent mechanisms for ensemble face processing.

Acknowledgement: This research was supported by an NSERC Discovery Grant to J.S.C. and A.N..

23.471 **Encoding the Naturalness of Crowds** Megan Dorn[1](megandorn7@berkeley.edu), Allison Y Leib[1], David Whitney[1]; [1]University of California, Berkeley

In television, movies, and video games, we are exposed to a diversity of human faces ranging in naturalness. Some faces appear entirely human, other faces appear entirely artificially generated, while still others fall along a continuum between these two extremes. Encoding the average naturalness of crowds may facilitate a more/less immersive media experience. In order to determine whether viewers are able to encode the naturalness of faces in a brief glance—we choose 100 face stimuli varying in naturalness. Participants from Amazon Mechanical Turk viewed each face for 1 second. Once the face disappeared, participants rated each face on a Likert scale, with 1 representing the most natural-appearing face and 10 representing the least natural-appearing face. The raters were highly reliable in their judgements of naturalness, and we used their ratings as a baseline for the next experiment. In Experiment 2, we generated groups of faces from the stimulus set. Each group was comprised of 6 faces and the average naturalness of the crowds varied from 3 to 7 on the Likert naturalness scale. New participants from Amazon Mechanical Turk participated in this experiment. On each trial, participants viewed the crowds of faces for a limited exposure duration. Once the crowd disappeared participants responded using the Likert scale to report the average naturalness of the crowd. We used a bi-variate correlation to compare participants' judgments of the average naturalness of the crowd of faces to the baseline ratings taken from independent observers in Experiment 1. The judgements from the two independent groups were significantly correlated, strongly indicating that participants are able to perceive the ensemble naturalness of crowds.

23.472 **A visual search advantage for illusory faces in inanimate objects** Robert T Keys[1](robert.tobin.keys@gmail.com), Jessica Taubert[2], Susan G Wardle[1]; [1]Department of Cognitive Science, Macquarie University, Sydney, Australia, [2]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, Bethesda, MD, USA

The spontaneous misperception of a face in an inanimate object—face pareidolia—is a common experience. This readiness to perceive faces might indicate a broadly-tuned mechanism that facilitates rapid face detection in cluttered environments. Although several studies have reported a visual search advantage for real faces, it is unclear to what degree this is driven by low-level features characteristic of faces. A key feature of pareidolia is that face perception occurs in the absence of the typical visual properties. Here we used a visual search paradigm to investigate whether there is a visual search advantage for naturally-occurring illusory faces in inanimate objects. In Experiment 1 (N = 18), search targets were 26 examples of face pareidolia in everyday objects (e.g., cheese graters, electrical sockets), and a yoked set of 26 objects matched for object content, but without illusory faces. Each yoked target pair had a corresponding set of 64 unique object-matched distractors. Participants searched for targets amongst 16, 32, or 64 matched distractors in an 8×8 grid display. In Experiment 2 (N = 18), search targets were 23 illusory faces, 23 matched objects, and 23 real faces. Participants searched for targets amongst 4, 8, or 16 diverse distractors in a circular display. Search times were faster for illusory faces than for matched objects amongst both highly homogenous (Experiment 1) and heterogeneous (Experiment 2) distractors. We found no interaction between set size and target type in Experiment 1, suggesting that despite faster overall search times, illusory faces do not 'pop-out' amongst matched objects. In Experiment 2, search times for real faces were faster and more efficient than for illusory faces or matched objects. The results indicate that face-like features improve visual search, and are consistent with the view that low-level visual properties may drive previous reports of pop-out for real faces.

Acknowledgement: Australian National Health & Medical Research Council (NHMRC) Early Career Fellowship (APP1072245), Macquarie University Research Development Grant

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Color and Light: Lightness and brightness

Saturday, May 19, 8:30 am - 12:30 pm

Poster Session, Pavilion

23.473 **A computational mid-level model of lightness perception** Richard F Murray[1](rfm@yorku.ca); [1]Department of Psychology and Centre for Vision Research, York University

Current approaches to lightness perception include low-level and mid-level models. Low-level models are computational, but have no representation of important factors such as lighting conditions. Mid-level models incorporate such factors, but are typically conceptual rather than genuinely computational, and this limits both their usefulness and our ability to derive testable predictions from them. Here I use Markov random field (MRF) methods to develop a computational mid-level model of lightness perception. The model makes simple statistical assumptions about local patterns of lighting and reflectance, and uses belief propagation and simulated annealing to find globally maximum a posteriori estimates of lighting and reflectance in stimulus images. To simplify this first implementation, I model lightness perception in stimuli on a 16 x 16 pixel grid; within this constraint one can recreate many lightness illusions (e.g., the argyle illusion) and many lightness phenomena (e.g., simultaneous contrast). The model assumes that (1) reflectance spans the range 3% to 90%, (2) illuminance (incident lighting) spans 0 to 100,000 lux, (3) illuminance edges are less common than reflectance edges, (4) illuminance edges tend to be straighter than reflectance edges, and (5) reflectance and illuminance edges usually occur at image luminance edges. Guided by these few simple assumptions, the model arrives at human-like interpretations of lightness illusions that have been problematic for previous models, including the argyle illusion, snake illusion, Koffka ring, and their control conditions. The model also reproduces important phenomena in human lightness perception, including simultaneous contrast and anchoring to white. Thus an MRF model that incorporates simple assumptions about reflectance and lighting provides a strong mid-level computational account of lightness perception over a wide range of conditions. It also illustrates how MRFs can be used to develop more powerful models of constancy that incorporate factors such colour and 3D shape.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

23.474 **Investigation of Lightness Illusions in Artificial Neural Networks** Leslie Wöhler[1](woehler@cg.cs.tu-bs.de), Marcus Magnor[1]; [1]Institut für Computergraphik, Technische Universität Braunschweig

There has been extensive research on lightness illusions like Herman grids and Mach bands as they offer fundamental insights in human perception and the processes in the human visual system. Inspired by the data processing of the human neural network, artificial neural networks currently achieve state-of-the-art results for challenging tasks including object classification and detection. We investigated how different artificial neural networks trained to decompose albedo and illumination information of input images perceive well-known lightness illusions. In 2007, Corney et. al. constructed an artificial neural network to solve this decomposition task and found that its perception of lightness illusions was very similar to humans. To gain more insight, we created and trained a convolution neural network (CNN) on the same dataset and compared the results. Moreover, we retrained the original artificial neural network on a synthetic dataset and included comparisons for four pretrained, published CNNs, which are all designed for the same task but utilize different architectures and training data. We found significant differences between the different artificial neural networks. The original network by Corney et. al. perceived all tested illusions similar to humans. Even though we used the same training data, our CNN behaves differently and responds to less illusions. Changing the training data to an artificial dataset while keeping the same architecture as Corney et. al. also changes the networks behavior and prevents it from perceiving some of the illusions. Moreover, two of the pretrained, published CNNs were trained on the same dataset and display similar behavior towards illusions. We conclude that the architecture as well as the training data influence the perception of lightness illusions for artificial neural networks. In our experiments the CNNs were more robust to these illusions than the artificial neural networks without convolutional layers.

23.475 **Contrast dependent brightness shift induced by contextual motion** Sang Wook Hong[1](shong6@fau.edu), Min-Suk Kang[2]; [1]Department of Psychology and Center for Complex Systems and Brain Sciences, Florida Atlantic University, [2]Department of Psychology, Sungkyunkwan University

Brightness of an object is determined by spatial context as well as light intensity reflected by the object. A recent study demonstrates that an object's motion can alter brightness of the moving object itself and also brightness of a nearby stationary object (Hong & Kang, 2013). For example, when a dark gray stationary dot is presented with a physically identical moving dot on a white background, the stationary dot appears brighter (brightness shift toward background) and the moving dot appears darker (brightness shift away from the background) than the brightness measured without any motion. In the current study, we investigated how contrast between objects and surrounding uniform background, and contrast between moving and stationary objects affects the motion-induced brightness shift. Brightness of a stationary and a moving dot was separately measured using memory-based choice task, while either the contrast between the dots and the background or the contrast between the stationary and the moving dots was systematically varied. We found that, first, brightness of the stationary dot shifted toward the background and brightness of the moving dot shifted away from the background when contrast between the dots and background was high, consistent with the previous finding. However, when the contrast was low, the direction of brightness shift in the stationary dot was reversed. Second, the magnitude of brightness shift was significantly reduced as a function of the contrast between the stationary and moving dots. We discussed underlying mechanisms mediating the contrast dependent motion-induced brightness shift.

23.476 **Brightness Induction Enhancements and Limitations at Low Frequency Modulations Across a Variety of Stimulus Contexts** Arash Yazdanbakhsh[1,2,3,4](yazdan@bu.edu), Louis Vinke[2,3]; [1]Psychological & Brain Sciences, Boston University, Boston, MA 02215, [2]Graduate Program for Neuroscience, Boston University, Boston, MA 02215, [3]Center for Systems Neuroscience, Boston University, Boston, MA 02215, [4]Center for Research in Sensory Communications and Neural Technology (CReSCNT)

Brightness illusions are most often studied under static viewing conditions with figures varying in geometric design. By temporally modulating the surrounding context of the illusions, slow frequencies can induce corresponding brightness phenomena at the same frequency, up until a temporal limit or cut-off frequency for brightness induction at higher frequencies. It is unclear if brightness illusions containing different stimulus configurations operate over similar temporal modulation frequencies, and in general the extent to which brightness induction or perceived lightness can be sustained as temporal modulation frequency is increased. In contrast to previous temporal modulation studies with matching paradigms, we designed a novel nulling paradigm to probe participants' perceived lightness of a central gray region encompassed by different contextual surrounds, known to induce brightness illusions under static conditions. The brightness induction strength was measured when the contextual surrounds were modulated continuously at certain frequencies, which was compared against brightness induction with no temporal modulation (static). Continuous surround modulation induced a significant increase (for 0.25 and 0.5 Hz) in the perceived lightness of the central gray region compared to the static condition for multiple classes of brightness induction stimuli, except when the figure-ground segmentation of the contextual surrounds are perceptually ambiguous. Brightness induction decreased significantly as temporal modulation frequency was increased for a subset of illusion types, while others with less prominent figure-ground organizations showed weaker trends. The brightness induction strength for certain illusions is strongest at very low or slow continuous temporal frequencies (0.25 to 0.5 Hz). Our results support previous work demonstrating cut-off frequencies exist, potentially imposed by the amount of time necessary to integrate the stimulus components in a visual scene. Our key finding demonstrates that a much lower critical frequency below the cut-off frequency exists, which maximally enhances brightness induction, and is dependent on the prevalence of figure-ground organization.

23.477 **Using conjoint measurement to estimate scales of perceived surface lightness**
Guillermo Aguilar[1](guillermo@bccn-berlin.de), Marianne Maertens[1]; [1]Modelling of Cognitive Processes Group, Technische Universitaet Berlin

Maximum likelihood difference scaling (MLDS; Maloney & Yang, 2003) is a straightforward and intuitive method to measure perceptual scales. We adopted MLDS to measure lightness scales in different contexts, such as plain view and various transparency conditions, and we showed that it was possible to predict lightness matches across different contexts. One great benefit of MLDS is that it only ever asks observers to compare entities that are seen under identical conditions. However, to compare perceptual scales across conditions they need to be anchored to a common origin, which by default is chosen to be zero and which might not always be the best choice. Maximum likelihood conjoint measurement (MLCM; Knoblauch & Maloney, 2012) asks observers to do within and across context comparisons of targets and estimates various scales whereby one of the scales serves as a reference and all other scales are expressed relative to the first scale. Here, we compared scales estimated with MLDS and MLCM. We measured scales of perceived lightness in rendered images of variegated checkerboards seen in plain view or through a transparent medium. The transparency compresses and shifts the luminance range with respect to plain view. For MLCM we used the method of paired comparisons, and for MLDS we used the method of triads where observers indicate which of two pairs of checks appears more different in lightness. We simulated responses from theoretical lightness scales assuming varying degrees of lightness constancy. MLCM and MLDS were both able to recover the theoretical lightness scales. MLCM was able to detect cases of partial lightness constancy for which MLD scales might be confounded. Experimentally we found that scales derived with MLCM were consistent with those from MLDS. MLCM might be a valuable alternative to MLDS when the perceptual magnitudes under study exhibit less constancy than perceived surface lightness.

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23.478 **The effects of context on face lightness perception**
Yin Yan Cheang[1](yycheang@connect.hku.hk), Dorita H. F. Chang[1]; [1]Department of Psychology, The University of Hong Kong, Hong Kong

The other-race effect (ORE) refers to better encoding of own-race faces, resulting in better face recognition or memory capacity. Previous research in our lab has suggested a contextual influence, specifically in the form of an ORE, in face lightness perception. Specifically, Chinese participants performed the best when matching face luminance against their own-race faces and equally worse when matching against other-race (Caucasian and African-American) faces. Here, we further probed the strength of race-based contextual influences on face luminance judgments by asking Caucasian participants who grew up in predominantly own-race settings to perform a face-luminance matching task. We also tested whether face luminance judgments are susceptible to the face-inversion effect (FIE), as reflected in impaired perception when faces are inverted. On each trial, participants were asked to adjust the luminance of a target face to match that of the reference face. Matches involved same-race and cross-race stimuli shown in upright and inverted orientations. While we did not find effects of face orientation on luminance judgments, we found a significant race effect for cross-race trials, although in an unexpected direction: participants demonstrated the smallest matching distortion when matching against Chinese faces, and the greatest distortion when the reference faces were African-American. We suggest that high-level knowledge (i.e., of race categories, and of race-specific luminance distributions) can modulate luminance perception by impeding (or enhancing) mean luminance estimation for faces of different races.

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Saturday Afternoon Talks

Perception and Action: Performance

Saturday, May 19, 2:30 - 4:15 pm, Talk Room 1

Moderator: Stephanie Rossit

24.11, 2:30 pm **Predicting how we grasp arbitrary objects** Lina K Klein[1](Lina.K.Klein@psychol.uni-giessen.de), Guido Maiello[1], Daria Proklova[2], Juan Chen[2], Vivian C Paulun[1], Jody C Culham[2], Roland W Fleming[1]; [1]Department of Psychology, Justus-Liebig University Giessen, [2]Department of Psychology, Brain and Mind Institute, University of Western Ontario

We investigated the computations underlying visually guided grasp selection for three-dimensional objects of non-uniform materials, and the brain areas involved in this process. In behavioral experiments, 26 participants picked up objects composed of 10 cubes (individual cubes made of wood or brass, side length 2.5 cm) in various configurations to test how an object's visually perceived three-dimensional shape and material properties affect grasp locations. We built 16 objects (4 shapes x 4 material configurations) which we presented to participants in 2 orientations. The results reveal that grasping is highly regular, constrained, and consistent across participants. Specifically, grasp locations are systematically affected by overall weight as well as mass distribution, the length of the reach trajectory, the subject's natural grip axis, and shape properties such as the presence of obvious handles. We employed these findings to develop a generalized grasp selection model which predicts human grasp locations strikingly well (essentially as well as individuals predict one another). Based on the model's predictions we created a new set of shapes and a pre-selected subset of grasp positions designed to tease apart the different components of visual grasp selection. For example, some grasps were optimal with respect to the human natural grip axis, but suboptimal with respect to minimizing net torque acting on the object, and vice versa. In a functional magnetic resonance imaging (fMRI) experiment, we recorded BOLD activity while participants planned and executed grasping with the new set of objects at the pre-selected grasp points. We used representational similarity analysis on the voxel activation patterns to test how well different model components accounted for the activation patterns in various brain regions. Thus, by combining behavioral data, computational modelling, and fMRI we can predict how humans grasp objects.

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24.12, 2:45 pm **Planning ahead: preparatory EEG activity predicts voluntary actions when the goal is not immediately accessible to perception** Ori Ossmy[1](oriossmy@gmail.com), Brianna E Kaplan[1], Danyang Han[1], Melody Xu[1], Roy Mukamel[2], Karen E Adolph[1]; [1]Department of Psychology and Center of Neural Science, New York University, NY, USA, [2]Sagol School of Neuroscience and School of Psychological Sciences, Tel-Aviv University, Tel-Aviv, Israel

Action planning is required when using a tool flexibly in a changing environment. Humans achieve this by keeping both the initial contact with the tool and the end goal in mind, even when the end goal stretches far into the future. For example, to grasp a hammer to pound a peg when the handle points toward their non-dominant hand, humans use an underhand initial grip to allow for a smooth transition to an effective end grip. Accumulating research over the past decades suggests that neural activity during the time interval preceding voluntary action is associated with different aspects of the forthcoming motor act. However, little is known about the neural underpinning of flexible action planning when the end goal is not immediately accessible to perception. Here, we developed a novel setup that allowed us to obtain electroencephalography (EEG), head-mounted eye tracking, motion tracking, and video data simultaneously. We collected data from 22 healthy adult subjects while they performed a hammer-and-peg task when: (1) the handle pointed towards their dominant hand; or (2) the handle pointed towards their non-dominant hand. The different directions of the hammer required subjects to be flexible and change their initial grip to accomplish the hammering goal effectively. We found that neural activity during the time interval preceding movement onset (250ms) over the contralateral sensory-motor electrodes significantly predicts how subjects use the tool. Moreover, we used machine learning algorithms to examine the relations between pre-movement perceptual information (recorded from the eye-tracker) and the neural activity (recorded from EEG) and whether combining both improves the prediction of future action (recorded from motion-tracker and video). Our results demonstrate the formulation of a plan in the motor cortex before flexible actions, and have implication for the control of sophisticated Brain-Machine Interfaces (BMIs).

Acknowledgement: NSF/SBE-BSF-1627993

24.13, 3:00 pm **Decoding typical (but not atypical) actions with real tools from both dorsal and ventral visual stream regions** Ethan Knights[1](ethan.knights@uea.ac.uk), Fraser W. Smith[1], Courtney Mansfield[1], Diana Tonin[1], Holly Weaver[1], Jenna Green[2], Janak Saada[2], Stephanie Rossit[1]; [1]School of Psychology, University of East Anglia, Norwich, UK, [2]Department of Radiology, Norfolk and Norwich University Hospitals NHS Foundation Trust, Norwich, UK

Tools are manipulable objects that, unlike other objects in the world (e.g., buildings), are tightly linked to highly predictable action procedures. Neuroimaging has revealed a left-lateralized network of dorsal and ventral visual stream regions for tool-use and knowledge, but the exact role of these regions remains unclear. Moreover, studies involving actual hand actions with real tools are rare as most research to date used proxies for tool-use including presenting visual stimuli (e.g., pictures) or action simulation (e.g., pantomime). Here we used functional magnetic resonance imaging (fMRI) and multi-voxel pattern analysis (MVPA) to investigate whether the human brain represents actual object-specific functional grasps with real 3D tools. Specifically, we tested if patterns of brain activity would differ depending on whether the grasp was consistent or inconsistent with how tools are typically grasped for use (e.g., grasp knife by handle rather than by its serrated edge). In a block-design fMRI paradigm, 19 participants grasped the left or right sides of 3D-printed tools (kitchen utensils) and non-tool objects (bar-shaped objects) in open loop with the right-hand. Importantly, and unknown to participants, by varying movement direction (right/left) the tool grasps were performed in either a typical (by the handle) or atypical (by the business end) manner. In addition, for each participant separate functional localizer runs were obtained to define regions of interest. MVPA showed that typical vs. atypical grasping could be decoded significantly higher for tools than non-tools in hand-selective regions of the lateral occipital temporal cortex and intraparietal sulcus. None of the body-selective, tool-selective or object-selective areas discriminated typical vs. atypical grasps with tools higher than non-tools. These results indicate that dorsal and ventral hand-selective regions contain representations of how to appropriately interact with tools and that these are evoked even when they are irrelevant to task performance.

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24.14, 3:15 pm **The visual control of walking over terrain with multiple raised obstacles** Brett Fajen[1](fajenb@rpi.edu), Sean L Barton[1], Scott T Steinmetz[1]; [1]Cognitive Science Department, RPI

When humans walk over flat terrain with regions of unsafe footholds (puddles, patches of ice), visual information from two step lengths ahead is sufficient to maintain forward progress and ensure proper foot placement (Matthis & Fajen, 2013, 2014). However, when the terrain varies in elevation, walkers must also ensure that they avoid colliding with obstacles as the feet move from one foothold to another. The aim of the present study was to determine how far ahead along the future path walkers need to see to negotiate terrain with multiple raised obstacles. Subjects (N = 14) walked along a short path while attempting to avoid stepping on or

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colliding with virtual obstacles. The obstacles were projected onto the floor by a 3D-capable projector and viewed through shutter glasses (Diaz et al., 2015), giving the impression of a textured ground surface upon which rested an array of randomly distributed 3D blocks. There was also a control condition in which the obstacles were 2D (i.e., flat). To assess how changes in visual look-ahead affect walking behavior, obstacles were visible only when they fell within a circular visibility window centered on the subject's head. Visibility window size varied between 1.0 and 4.0 step-lengths, and there was also a control condition is which the entire obstacle array was visible throughout the trial. As visibility window size decreased, subjects walked slower and were more likely to collide with obstacles in both the flat and raised obstacle conditions. However, effects of the visibility window manipulation were observed at larger window sizes in the raised-obstacle condition, suggesting that walkers require visual information from farther ahead when obstacles are elevated. Additional analyses suggest that such information could be used to more precisely control foot placement and elevation and to select routes that avoid more difficult obstacle configurations.

Acknowledgement: NSF 1431087

24.15, 3:30 pm **Measurement noise explains lack of full adaptation without the need of forgetting: evidence from temporal delays.** Elisabeth B. Knelange[1,2](l.knelange@ub.edu), Joan López-Moliner[1,2]; [1]Department of Cognition, Development and Educational Psychology, [2]Institute of Neurosciences, University of Barcelona

Predicting the temporal consequences of our motor commands is a necessary skill for many daily activities. We optimize these predictions by using sensory error signals. Errors can stem from inaccurate predictions, but also from noise in the sensorimotor system or other external influences. The brain therefore needs to assess which errors need to be corrected for and which do not. Many studies have used perturbation paradigms to study our ability to predict the consequences of our actions, but adaptation to the perturbation is often not complete. State-space models of motor learning have attributed this lack of adaptation to a trial-to-trial forgetting factor. To explain the lack of adaptation, we propose a more parsimonious alternative, which does not involve forgetting. A temporal perturbation that is introduced during a motor task increases uncertainty in the measurement. To investigate if this added uncertainty could provide a more simple explanation for the lack of adaptation, we modeled participants' adaptation to a gradually increasing delay in a simple motor task. A target on a screen moved horizontally towards a vertical line (at different speeds/distances). Participants were instructed to press a button when the target reached the line. In separate conditions either visual or auditory (unisensory), or combined (mulitsensory) feedback was provided when the subject pressed the button. Each condition consisted of 135 trials and the sensory feedback of the button-press was gradually delayed with 1 ms/trial. Participants started accounting for these delays by pressing the button earlier. We modeled the behavior of the participants with a non-stationary Kalman filter, in which the measurement error increased gradually with the delay. Our model could not only explain the lack of adaptation to the imposed delay, but also the higher adaptation to multisensory versus unisensory feedback, which could not be explained by a forgetting factor.

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24.16, 3:45 pm **Impairment of "vision for action" functions in the newly sighted, following early-onset and prolonged visual deprivation** Ehud Zohary[1](udiz@mail.huji.ac.il), Itay Ben Zion[2], Caterin Schreiber[1], Ayelet McKyton[1]; [1]The Edmond and Lily Safra Center for Brain Sciences and Neurobiology Department, The Hebrew University of Jerusalem , [2]Goldschleger Eye Institute, Chaim Sheba Medical Center and Sackler School of Medicine, Tel-Aviv University

Understanding others' actions is an essential aspect of behavior (e.g. for social interaction). In fact, we can often predict the outcome of an action well before its completion. Furthermore, some of our actions are triggered by automatic processes elicited by observing others' actions: Infants recognize the target of gaze of others, and direct their gaze to the same object within months from birth. Similarly, we better imitate actions when they are spatially congruent with others' actions. Still, it is unclear if these behaviors are innate or require visual experience to develop. We tackled these issues by studying a unique group of newly-sighted children that suffered for years from dense bilateral cataract since early infancy. After cataract removal surgery, their visual acuity typically improved considerably allowing most of them to recognize hand actions or gaze direction. In the first experiment, the subjects watched videos of hand-action showing either grasping or pointing to an object. The object was located at the left or right side of the screen. They reported the action type (pointing / grasping) and direction (left/right) on each trial. The newly-sighted required longer action-video presentations to discriminate between the two actions, whereas age-matched controls performed equally well in both tasks. We also tested if viewing a specific hand action (tapping with one hand), would speed up the response-compatible action (e.g. automatic imitation), and whether seeing a person gazing in one direction would facilitate reaction to the gaze-compatible target. The newly-sighted were less affected by such viewed-actions (hand action or gaze direction) than controls, even two years after the operation. Collectively, our result suggest that visual experience is necessary for the development of automatic "action understanding" behavior. At the very least, our results indicate that if these behaviors were based on innate mechanisms, they are susceptible to long periods of visual deprivation.

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24.17, 4:00 pm **Investigating the Differences in Predictive Oculomotor Strategies using Long Short-Term Memory Recurrent Neural Network Models** Kamran Binaee[1](kamranbinaee@mail.rit.edu), Rakshit S Kothari[1], Jeff B Pelz[1], Gabriel J Diaz[1]; [1]Rochester Institute of Technology

The mapping between current visual information and future motor action is not clear especially when the task demands require predictive strategies, as when intercepting a fast-moving ball. In this study, we collected hand, head, and gaze movement of ten subjects performing a virtual ball catching task in which they were instructed to intercept a parabolically moving virtual ball using a badminton paddle. We forced subjects to use prediction by making the virtual ball disappear for a fixed 500 ms duration occurring 300, 400 or 500 ms before it passed the subject. To investigate perceptual contributions to successful visuo-motor behavior, we created supervised Long Short-Term Memory Recurrent Neural Network (LSTM-RNN) model for each subject of different ability as indicated by their catching rate and compared the properties of the models. The model takes egocentric visual information of the ball, head, gaze, and hand position/orientation as input, and produces the next position/orientation of the gaze, head, and hand. Models trained on more successful subjects are able to anticipate the subject's actions more accurately and further in time, suggesting a stronger relationship between temporally distant visual information and motor output. To investigate the relative influence of particular sources of visual information on the motor output, we conducted an ablation study in which at each iteration, one visual feature (such as expansion rate) was removed from the model, and inferred its reliability from the subsequent change in model performance. The model fit to the more successful group's data was more sensitive to the ablation of ball-related visual features. This suggests that the model fit to data from the more successful group had found the temporal mapping between ball visual features and output motor action, rather than heavily relying on a temporal extrapolation of future motor output based on previous timesteps.

Visual Working Memory

Saturday, May 19, 2:30 - 4:15 pm, Talk Room 2

Moderator: Roy Luria

24.21, 2:30 pm **An object-based pointer system in visual working memory** Halely Balaban[1,2](halelyba@mail.tau.ac.il), Trafton Drew[3], Roy Luria[1,2]; [1]Sagol School of Neuroscience, Tel Aviv University, [2]The School of Psychological Sciences, Tel Aviv University, [3]Psychology Department, University of Utah

Visual working memory (VWM) representations must be stably mapped to the relevant stimuli in order to guide behavior. This "pointer system" (e.g., Pylyshyn, 2000) allows the correct representation to be accessed and updated following changes. A loss of this mapping makes updating impossible, and instead triggers a resetting process, namely removing the

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unmapped representation and re-encoding the new information (Balaban & Luria, 2017). Since resetting indicates a loss of the stimuli-to-representations mapping, it can be used to study the pointer system: changes that trigger resetting presumably involve factors that are critical to the pointer system. In a feature-updating task, we utilized the ERP signature of resetting to ask whether the pointers operate in an object-based or feature-based manner. We used moving colored-shapes in a change-detection task. In different blocks, either the shape or the color were relevant. During the movement, items could separate into independently moving shape-halves. In the shape-task, the separation not only destroyed a previously coherent object, but also changed the task-relevant dimension. In contrast, in the color-task the separation left the colors identical, destroying only the objects while maintaining the task-relevant features (colors). Critically, the results indicated that separation destroyed the mapping in both tasks, regardless of the relevant dimension, triggering a resetting process with a drop in the contralateral delay activity (the ERP marker of VWM) amplitude. This suggests the pointers system is object-based. An extreme object-based prediction is that in a color change-detection task, even a colored square's separation into two identical colored rectangles should produce resetting, as long as the initial colored square was encoded as one object. In another experiment this was indeed found, further corroborating an object-based mapping. Aside from supporting objects' role in VWM's pointer system, our results demonstrate that resetting can reveal how internal representations relate to the outside environment.

Acknowledgement: BSF, ISF

24.22, 2:45 pm **Attention fluctuates rhythmically between objects in working memory** Benjamin Peters[1](peters@med.uni-frankfurt.de), Benjamin Rahm[2], Jochen Kaiser[1], Christoph Bledowski[1]; [1]Institute of Medical Psychology, Goethe-University Frankfurt, [2]Medical Psychology and Medical Sociology, Albert Ludwigs University of Freiburg

Attention prioritizes relevant information based on spatial locations, features, or objects. Recently, it has been shown that attention is not allocated in a sustained and stable way but rather fluctuates periodically across time. In particular, object-based attentional selection leads to rhythmic patterns in detection rates that differ between attended and unattended objects. Working memory (WM) is hypothesized to utilize the same attentional mechanisms as perception. In support of this view, we have demonstrated that the principles of object-based attention in perception also apply to WM: Participants shifted their attention between memorized spatial positions faster within the same object than across different objects. We replicated this same-object benefit in the present study. Importantly, to test whether attention similarly fluctuates periodically between objects in WM, we manipulated the interval of a cued attentional shift in WM and the subsequent probe from 200 to 1000 ms with high temporal resolution. We observed that the same-object benefit was periodically modulated across time, corresponding to a rate of approximately 6Hz. In addition, the fluctuations at the attended object and the unattended object showed an anti-phase relationship, suggesting that attention alternated periodically between objects held in WM. These results suggest that the allocation of attention in WM is rhythmically modulated, supporting the hypothesized correspondence between attentional mechanisms in perception and WM.

24.23, 3:00 pm **Episodic Memory Replaces Active Maintenance in Working Memory When Available** Mark W Schurgin[1](maschurgin@gmail.com), Corbin A Cunningham[2], Howard E Egeth[2], Timothy F Brady[1]; [1]Psychology, University of California, San Diego, [2]Psychological & Brain Sciences, Johns Hopkins University

Humans have remarkable episodic long-term memory abilities, capable of storing thousands of objects with significant detail (Shepard, 1967; Standing, 1973; Brady, Konkle, Alvarez, & Oliva, 2008). However, it remains unknown how episodic long-term memory is utilized during the short-term maintenance of information. Specifically, if people have an episodic memory for an item, how does this affect subsequent working memory for that same item? To address this, participants were shown two objects they needed to hold in working memory in order to make a subsequent perceptual discrimination based on one of the two objects. We found that when a participant encounters an object that was previously encoded in episodic memory, they maintain approximately half as much perceptual information actively in working memory as when they were shown two completely new objects ($t(19)=2.57$, $p=0.02$) as indexed by the CDA - a well-known neural signature reflecting the active storage of perceptual information (Vogel & Machizawa, 2004). Despite maintaining significantly less information actively in working memory, participants did not demonstrate any differences in behavioral performance ($t(19)=0.92$, $p=0.37$). Thus, people can dynamically disengage working memory when episodic memory is available without incurring a cost. However, this does not mean that participants always utilize episodic memory when it is available. In a follow-up experiment we introduced substantial perceptual interference into the working memory task and found that participants actively stored items in working memory even when they had existing episodic memories of those items. These results clarify the conditions under which episodic and working memory operate. Specifically, working memory is engaged when new information is encountered or when perceptual interference is high. Episodic memory is otherwise utilized in lieu of working memory, if available. These data demonstrate the interactions between working memory and episodic memory are much more dynamic and fluid than previously thought.

24.24, 3:15 pm **Visual Search Within Working Memory** Garry Kong[1](kong.garry@nyu.edu), Daryl Fougnie[1]; [1]Science Division, New York University Abu Dhabi

Attention and working memory are two key pillars of cognition. Despite much research, there are important aspects about the relationship between the two constructs that are not well understood. Here we explore the similarity in the mechanisms that select and update working memory to those that guide attention during perception, such as in visual search. We use a novel memory search task where participants memorize a display of objects on a 4x4 grid. During memory maintenance, participants are instructed to update the spatial positions of a subset of objects. This updating process is self-paced—its speed reflecting the accessibility of the to-be-updated subset. Using this task, we explored whether landmark findings in visual search would hold true for memory search. In Experiment 1 (n=12), we found a search asymmetry—it was easier to access memory representations defined by a feature than defined by the lack of a feature, $t(11) = 4.13$, $p = .002$. In Experiment 2 (n=12) we found target-distractor similarity effects—updating a single target was easier when the distractors were farther away in feature space, $t(11) = 3.29$, $p = .007$. In Experiment 3 (n=12) we found a feature versus conjunction benefit—access times were much faster for instructions to move objects defined by only one feature (e.g., all triangles) as opposed to a conjunction of features (e.g., all red triangles), $t(11) = 2.66$, $p = .022$. Taken together, our results suggest a common coding and selection scheme for working memory and perceptual representations.

24.25, 3:30 pm **Memory load modulates the dynamics of visual working memory.** Matthew F Panichello[1](mfp2@princeton.edu), Brian D DePasquale[1], Jonathan W Pillow[1,2], Timothy J Buschman[1,2]; [1]Princeton Neuroscience Institute, Princeton University, [2]Department of Psychology, Princeton University

Working memory is imperfect and dynamic – memories becomes less accurate with time. We combine psychophysical methods and computational modeling to precisely describe the dynamic forces governing working memory. We show that the accumulation of error in working memory over time is not random but reflects underlying attractor dynamics. Furthermore, these dynamics are modulated by memory load and they are modified by experience: memories drift towards common stimuli. To identify these attractor dynamics, we trained both monkeys and humans to perform a continuous-report working memory task. In brief, subjects were asked to remember 1 to 3 colored squares. After a variable memory delay, subjects had to report the color of a cued stimulus on a continuous color wheel. Dynamic models fit to the behavioral responses of both monkeys and humans showed random diffusion dominated the dynamics at low memory load but strong attractors dominated dynamics at high memory load. In other words, memory dynamics are load-dependent: attractor depth increased with the number of items in working memory. These results provide a mechanistic explanation for why increasing the number of items in memory impairs memory accuracy and provide a bridge between descriptive models of memory reports and neural network models of working memory.

Acknowledgement: MFP was supported by a National Defense Science and Engineering Graduate Fellowship, BDD was supported by a grant from the Simons Collaboration on the Global Brain (to JWP and CDB), JWP was supported by grants from the McKnight Foundation, Simons Collaboration on the Global Brain (SCGB AWD1004351) and the NSF CAREER Award (IIS-1150186), and TJB was supported by a grant from the Office of Naval Research (ONR N00014-16-1-2085).

24.26, 3:45 pm **Optimal change detection without ensemble statistics** William J Harrison[1,2](willjharri@gmail.com), Paul M Bays[1]; [1]Department of Psychology, University of Cambridge, [2]Queensland Brain Institute, The University of Queensland

Despite experiencing a richly detailed visual world, our ability to remember the appearance of objects even for a fraction of a second is greatly limited. Recent studies have suggested that this limitation may be circumvented by storing higher-order regularities of a scene (i.e. ensemble or summary statistics) that typically aren't captured in lab-based experiments. Here we investigated the influence of ensemble statistics on working memory using a modified change detection task. An observer's task was to remember the colors of items in a sample display, and report whether a test display, presented one second later, was the same or different. Memoranda were two (Experiment 1) or four (Experiments 2 and 3) colored disks, randomly chosen from a circular color space. On change trials in Experiment 1 and 2, changes to individual colors were chosen to keep the mean the same, while changing the variance, or vice versa. In Experiment 3, we included a condition in which both the mean and variance changed. In Experiments 1 and 2, we found consistent evidence that sensitivity to a change in the mean color is the same as to sensitivity to a change in color variance. In Experiment 3 we found that sensitivity is not improved when both the mean and variance change, revealing these statistics do not additively influence performance. Indeed, rather than finding these ensemble statistics influenced memory performance, our results instead were precisely predicted by an ideal observer model that optimally summates evidence from each individual item independently of the group mean or variance. These results present a challenge to the claim that ensemble statistics are automatically extracted and stored in visual working memory.

Acknowledgement: Wellcome Trust (P.M.B.) NHMRC grant APP1091257 (W.J.H.)

24.27, 4:00 pm **Hemifield-specific control mechanisms for spatial working memory and attention: evidence from hemifield crossover costs.** Roger W Strong[1](rstrong@fas.harvard.edu), George A Alvarez[1]; [1]Department of Psychology, Harvard University

Tasks requiring divided attention are often performed better when attended items are presented bilaterally between the right and left visual hemifields, rather than contained within a single hemifield. This bilateral field advantage appears particularly pronounced for spatial tasks, such as multiple-object tracking (Alvarez & Cavanagh, 2005), spatial working memory (Delvenne, 2005; Umemoto, Drew, Ester, & Awh, 2010), and volitional perception of ambiguous motion (Nothelfer, Suzuki, & Franconeri, VSS 2015). However, it remains unclear whether these effects reflect hemifield-specific attentional control mechanisms, or instead result solely from hemifield-limited spatial interference during encoding. If hemifield-specific control mechanisms contribute to the bilateral field advantage, then maintaining spatial information should become more difficult when attended items cross between the two hemifields. Observers performed a spatial working memory task that required remembering the locations of dots presented in two separate grids. The grids were located in diagonally opposite quadrants during presentation of the dots (e.g., one grid in the top-right, and one grid in the bottom-left). After two dots were briefly presented in each grid, the grids simultaneously shifted either vertically to a new quadrant in the same hemifield (within-hemifield movement), or horizontally to a new quadrant in the opposite hemifield (between-hemifield movement), before a cue appeared in one grid. Observers were more accurate reporting whether this cue corresponded to a previous dot location following within-hemifield movements (M=86.0%) than following between-hemifield movements (M=79.5%; $t(59)=5.67$, $p< .001$). This crossover cost did not occur for a color working memory task (Experiment 2), but was found for a separate spatial attention task that required observers to maintain two distinct ambiguous motion perceptions (one vertical and one horizontal; Experiment 3). Together, these results provide converging evidence that hemifield-specific control mechanisms 1) contribute to the bilateral field advantage, and 2) may be a unique signature of spatial working memory and attention.

Faces: Emotion and social cues

Saturday, May 19, 5:15 - 6:45 pm, Talk Room 1

Moderator: Galia Avidan

25.11, 5:15 pm **Facial Color Is an Efficient Mechanism to Visually Transmit Emotion** Aleix M Martinez[1](aleix@ece.osu.edu), Carlos F Benitez-Quiroz[1], Ramprakash Srinivasan[1]; [1]The Ohio State University

Facial expressions of emotion in humans are believed to be produced by contracting one's facial muscles, generally called action units. Yet, the surface of the face is also innervated with a large network of blood vessels. Blood flow variations in these vessels yield visible color changes on the face. Here, we study the hypothesis that these visible facial colors allow observers to successfully transmit and visually interpret emotion even in the absence of facial muscle activation. To study this hypothesis, we address the following questions. Are observable facial colors consistent within and differential between emotion categories? Are observable facial colors consistent within and differential between positive and negative emotions (valence)? And, does the human visual system use these facial colors to decode emotion categories and valence from faces? These questions have, to the authors knowledge, never been assessed, yet suggest the existence of an important, unexplored mechanism of the production of facial expressions of emotion by a sender and their visual interpretation by an observer. The results of our studies provide the first evidence in favor of our hypothesis. Specifically, we use a machine learning algorithm to identify the most descriptive color features associated with each emotion category. This allows us to change the color of neutral face images (i.e., faces without any facial muscle movement) to match the color of specific emotions. Showing these images to human subjects demonstrates that people perceive the correct emotion category (and valence) on the face even in the absence of any muscle movement. We also demonstrate that this color signal is independent from that provided by facial muscle movements. These results support a revised model of the perception of facial expressions of emotion where facial color is an effective mechanism to visually transmit and decode emotion.

Acknowledgement: National Institutes of Health R01-DC-014498, and Human Frontier Science Program RGP0036/2016

25.12, 5:30 pm **Emotion Algebra reveals the richness of meanings of facial expressions** Carmel Sofer[1](carmelso@post.bgu.ac.il), Dan Vilenchik[1], Ron Dotsch[2], Galia Avidan[1]; [1]Ben Gurion University of Negev, Beer Sheva, Israel , [2]Utrecht University, Netherlands

Studies of emotional facial expressions generally reveal consensus among human participants about the social meanings of only six to fifteen basic expressions. Here we argue that perceivers use sequences of these expressions as the basis for generating a much larger, richer vocabulary of emotion states. Participants reviewed combinations of eight most consensual, static basic facial expressions, presented as a sequence of two images out of 8x8=64 possible sequences. They were required to describe in one word the "state of mind" of the person whose sequence of images was presented. To explore the perceivers' vocabulary of emotion states, we relied on computational methods, utilizing word embedding methods (Global Vectors for Word Representation) adapted from the field of Natural Language Processing. Our findings reveal that the perceived meanings of the sequences of facial expressions were a weighted average of the single expressions comprising them, resulting in 22 new emotion states, in addition to the eight basic expressions used in the experiment. An interaction between the first and the second expression in each sequence, indicated that each facial expression influenced the perception of the other expression, as well as the interpretation of the sequence as a whole. We also found that the product (i.e., interaction) of the vectors representing two sequential facial expressions predicted the consensus among participants about whether the sequence is commonly seen or not in daily life. This result supports the notion that algebraic vector opera-

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tions can predict human perception, shaped by past natural experience. Together, our findings suggest that the vocabulary of emotion states conveyed by facial expressions is rich and not limited, as it is the outcome of different combinations of these expressions that together creates a continuous space in which every emotion state is a weighted combination of the 8 basic emotions.

Acknowledgement: The study was supported by a grant from the Ministry of Defense in Israel to GA and CS. CS is also supported by the ABC initiative in Ben-Gurion University of the Negev.

25.13, 5:45 pm **Race at First Sight** Sasha Lasrado[1](caren.lasrado@unifr.ch), Nayla Sokhn[1], Kanji Tanaka[2], Katsumi Watanabe[2], Roberto Caldara[1]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg, Fribourg, Switzerland, [2]Department of Intermedia Art and Science, Waseda University, Tokyo, Japan

The human visual system is very fast and efficient at extracting socially relevant information from faces. Visual categorization studies employing foveated images have shown that human observers categorize other-race (OR) faces faster than same-race (SR) faces by race, producing an early perceptual bias termed the other-race categorization advantage (ORCA). Whether this perceptual advantage persists in the parafoveal visual field containing low spatial frequency, and which facial features are sampled during such categorization yet remain undetermined. To this aim, we recorded the eye movements of East Asian (EA) and Western Caucasian (WC) observers during a conventional foveal categorization by race of normalized WC and EA faces (FCRT, Experiment 1), a parafoveal saccadic reaction time (PSRT, Experiment 2) and a response time paradigm (PCRT, Experiment 3). EA and WC observers categorized OR faces faster than SR faces by race across all paradigms. However, this ORCA occurred at the rapid speed of just 300ms in the PSRT, almost twice as fast as in the manual response paradigms (PSRT < FCRT < PCRT: 300ms < 600ms < 750ms). Furthermore, fixation maps revealed a cultural perceptual bias in the FCRT, with WC observers sampling more the eye region and EA observers the central region of faces. Interestingly, such cultural contrast was abolished in the PSRT, with both groups deploying a single fixation to the middle of the eyes. Our PSRT data show that the speed of race categorization is boosted by visual field eccentricity, which eliminates unessential and time-consuming visual information processing. These findings also offer a novel explanation for eye-movement discrepancies reported on the cultural differences in face processing. Overall, our observations provide new evidence of race as a powerful rapid low-level visual signal transmitted by faces, which could relate to primitive functional mechanisms dedicated to the evolutionary-relevant social categorization of ingroup/outgroup members.

Acknowledgement: This work was supported by the Swiss National Science Foundation (grant number IZLJZ1_171065/1) awarded to Roberto Caldara.

25.14, 6:00 pm **Neural correlates of group bias during natural viewing** Timothy J Andrews[1](timothy.andrews@york.ac.uk), Philip IN Ulrich[2], Ryan K Smith[1], Richard L Hoggart[1], Andre Gouws[1]; [1]Department of Psychology, University of York, UK

To what extent do brains of different individuals operate in a similar manner? Previous studies have explored this issue by comparing the time-course of brain responses during natural viewing and have found a high level of correspondence in the brain responses across individuals. However, a variety of evidence has shown that individuals from different social groups can vary markedly in the way that they interpret the world. A key question in this regard is whether group differences in neural processing occur at early stages of processing when sensory information is encoded or whether they are evident at later stages of processing, which are more involved in interpreting the input. To explore the neural basis of these differences, we measured brain responses using fMRI from two groups of football supporters, while they watched a video of matches between their teams (Chelsea and Manchester United). First, we measured the time-course of responses in face-, place-, object- and body-selective regions of visual cortex. We found high correlations across individuals in the time-course of neural response across high-level visual cortex. A cluster analysis revealed distinct networks of activation among these regions during natural viewing. However, these high-level visual regions did not show any group differences. That is, the correlations in the neural response between individuals supporting the same team were not higher than between individuals supporting different teams. Regions that showed higher correlations for individuals from the same group were found in a network of frontal and subcortical brain regions that are involved in motor control, social cognition and reward. Together, these results suggest that group differences in processing visual input are not found in sensory regions of the brain, but are evident in regions that are involved in the evaluation and interpretation of the sensory signals.

25.15, 6:15 pm **Neural processing of others' gaze independent of specific facial features** Colin J Palmer[1](colin.palmer@unsw.edu.au), Kiley Seymour[1,2], Yumiko Otsuka[3], Colin WG Clifford[1]; [1]School of Psychology, UNSW Sydney, New South Wales 2052, Australia, [2]School of Social Sciences and Psychology, Western Sydney University, New South Wales, Australia, [3]Ehime University, Matsuyama, Ehime, Japan

Our sense of where another person is looking relies on perceptual integration of head and eye region information. For example, the feeling of being looked at by another person can be elicited by many different configurations of their head position and eye deviation. In primates, the anterior superior temporal sulcus (STS) is implicated in the visual processing of these facial features, but whether this region underlies our perceptual experience of others' direction of gaze is unknown. Here, we exploited a classic visual illusion in which identical eye regions are seen as looking in different directions depending on the orientation of the surrounding head. With functional MRI, we measured differences in neural activation in human observers (n = 12) to faces that appeared to be regarding them versus faces that appeared to be looking elsewhere, while exactly matching the facial features in the stimulus that combine to produce these percepts. This revealed a neural correlate of perceived gaze direction in anterior STS, namely an increased response when gaze was directed away from the observer. These data extend upon existing knowledge by identifying neural responses that reflect a sense of where other people are looking that is independent of the particular facial attributes that convey this information in a given moment.

Acknowledgement: This work was supported by the Australian Research Council (Discovery Project DP160102239). YO is supported by a Grant-in-Aid for Young Scientists (B) [17K13963] from the Japan Society for the Promotion of Science.

25.16, 6:30 pm **Gaze cueing is tuned to extract the mind behind the gaze: Investigations of 'gaze deflection'** Clara Colombatto[1](clara.colombatto@yale.edu), Yi-Chia Chen[2], Brian Scholl[1]; [1]Department of Psychology, Yale University, [2]Department of Psychology, Harvard University

The most salient 'social' visual stimuli we encounter are faces, and perhaps the most informative features of faces are eyes. Indeed, other people's eyes seem to be particularly meaningful to us, and perceived gaze can rapidly and automatically cause shifts of attention, as in the phenomenon of gaze cueing. But why is eye gaze so important? Presumably, gaze is meaningful not because of what it reveals about another person's eyes, but rather what it reveals about the mind behind the gaze — e.g. about what someone is attending to, or is intending to do. When you turn to look at something, however, it is not always because you are attending to it. Consider, for example, the familiar but unexplored phenomenon of 'gaze deflection' — when you are surreptitiously looking at someone and then suddenly look away when they catch you staring. In these cases, the 'deflected' gaze is not directed at anything in particular, but is only directed away from something (or someone) else. Do such 'deflected' gazes still orient other people's attention? To find out, we had subjects view videos of a person turning her head to look in a specific direction either to attend in that direction (Intentional gazes) or because she had just gotten caught staring at someone else and was looking away from that person (Deflected gazes). Gaze cueing (measured by the ability to identify a briefly flashed letter in the direction of a gaze) was stronger for Intentional gazes than for otherwise equivalent Deflected gazes — and this difference disappeared in control videos in which gaze did not appear to be 'deflected', even while controlling for other low-level visual properties. This shows how the process of gaze cueing is especially sophisticated — insofar as it is well-tuned to extract the 'mind' behind the gaze.

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Eye Movements: Neural mechanisms

Saturday, May 19, 5:15 - 6:45 pm, Talk Room 2

Moderator: Melissa Võ

25.21, 5:15 pm **Free-viewing fixation related EEG-potentials with continuous-time regression** Tim Cornelissen[1], Jona Sassenhagen[2], Melissa L.-H. Võ[1]; [1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, Frankfurt am Main, Germany, [2]Department of Psychology, FiebachLab, Goethe University Frankfurt, Frankfurt am Main, Germany

When recording eye movement and EEG data from observers free-viewing visual stimuli, a researcher faces numerous possible confounds. Two very pervasive confounds are temporally overlapping neural responses and variance in EEG signals that is related to eye movement parameters (such as fixation position or saccade amplitude). Typically, researchers have avoided these confounds by constraining eye movements, e.g. by instruction or stimulus design, or by limiting analysis to a-typically long fixations and to "similar" datasets (often relying on an incoherent application of null hypothesis significance testing to argue for similarity). These common approaches inevitably lead to the inclusion of only a constrained subset of eye movements, possibly not representative of general gaze behavior. Similarly, to truly capture the relationship between eye movements (EMs) and neural activity, it is suboptimal to influence or diminish eye movement effects between conditions before evaluating EEG data. Moreover, NHST should not be used to argue the absence of meaningful differences (Sassenhagen & Alday, 2016). Here, we present a way to address confounds by applying continuous-time regression with numerical covariates (Smith & Kutas, 2015), which involves explicitly modelling overlap and eye movement parameters. We show that this method accurately estimates the modelled confounds in real Eye Tracking-EEG data, thereby controlling for them. Additionally, we discuss EM-EEG relationships that require additional investigation, as well as practical considerations for the application of the method. We conclude that continuous-time regression opens up new venues for investigating neural correlates of visual processing in more natural contexts, such as during free-viewing.

Acknowledgement: This work was supported by DFG Grant VO 1683/2-1.

25.22, 5:30 pm **Extra-retinal mechanisms as compensation for retinal-circuit-level visual masking effects in saccadic suppression** Saad Idrees[1,2,3](idrees.sa@gmail.com), Felix Franke[4], Ziad M Hafed[1,5], Thomas A Münch[1,2,6]; [1]Werner Reichardt Centre for Integrative Neuroscience, Tuebingen, Germany, [2]Bernstein Center for Computational Neuroscience, Tuebingen, Germany, [3]IMPRS for Cognitive and Systems Neuroscience, Tuebingen, Germany, [4]Bio Engineering Laboratory, ETH Zurich, Basel, Switzerland, [5]Hertie Institute for Clinical Brain Research, Tuebingen, Germany, [6]Institute for Ophthalmic Research, Tuebingen, Germany

Perceptual suppression occurs robustly around saccades, but its underlying mechanisms are debated. On the one hand, purely visual masking effects may be sufficient; on the other, pathways for extra-retinal saccade-related corollary discharge exist. However, possible interactions between these two mechanisms remain unexplored. Here we show, using human psychophysics and retinal-circuit electrophysiology, that purely visual suppression[Office1] originates at the very first stage of the visual system in the retina itself, that it has a much longer time course than perceptual effects with real saccades, and that it dictates perceptual dependencies of suppression on image statistics. In the human experiments, 4 subjects located a low-contrast stimulus flashed at different times around saccades, while viewing a patterned background with 1 of 3 possible dominant spatial frequencies. In separate experiments, subjects maintained fixation and the background moved rapidly for 70 ms to "simulate" saccade-associated retinal image shifts. In ex-vivo retinal electrophysiology, we recorded retinal ganglion cell (RGC) activity in isolated mouse and pig retinae using multi-electrode arrays during a comparable simulated saccade paradigm. Critically, the same background and flash manipulations were employed. Perceptually, contrast sensitivity was reduced after both real and simulated saccades, but this reduction lasted significantly longer for simulated saccades. Suppression was also weakest and shortest for high spatial frequency backgrounds regardless of condition. RGC responses to flashes were also strongly modulated after rapid image shifts and with similar dependencies on background image statistics. Critically, RGC suppression lasted for much longer than in both perceptual experiments. We conclude that both visual and corollary discharge mechanisms may interact synergistically during saccadic suppression: retinal-circuit visual effects dictate the overall properties of saccadic suppression, including dependencies on image statistics, and corollary discharge signals instead act to dramatically shorten retinal-circuit masking effects which would otherwise last for up to ~1 second after every saccade.

25.23, 5:45 pm **Microcircuitry of visual performance monitoring in the supplementary eye field: Laminar distribution of error and reward processing.** Amirsaman Sajad[1](amirsaman.sajad@vanderbilt.edu), Jeffrey D Schall[1]; [1]Vanderbilt Vision Research Center, Center for Integrative and Cognitive Neuroscience, Department of Psychology, Vanderbilt University

Being error prone, the consequences of visual behavior must be monitored to achieve goals. In visuo-motor tasks neural signals arise in the supplementary eye field (SEF) when errors are made and when reward is expected. However, how these signals are orchestrated in laminar circuitry is unknown. We report the laminar organization of error and reward processing in neurophysiological data collected with linear electrode arrays (U-probe) sampling all layers of the SEF in two monkeys. From 16 perpendicular penetrations, we isolated 293 neurons across all layers of the SEF. Recordings were conducted while monkeys performed a visual saccade countermanding task. On ~60% of trials they made saccadic eye movement towards a visual stimulus but on a proportion of trials (~20%) made erroneous saccades despite an instruction to stop. After a short delay following the saccade, an auditory tone was presented which indicated the absence or presence of upcoming juice reward. Both monkeys adjusted performance following errors by slowing response time. Neurons that signaled errors before feedback presentation (n = 42) were observed in all layers. The earliest onset latency (< 100ms) was observed in lower L3 and L5 and spread later into L2 and L6. The magnitude of error-related modulation scaled with reward loss value. Neurons with higher discharge rate for positive feedback and/or reward gain (n = 51) were mainly located in lower layers, whereas those that exhibited elevated discharge rate for negative feedback or reward loss (n = 107) were mainly located in superficial layers L2/3 and lower L6. Response suppression (in response to positive outcomes) was commonly found in superficial layers, and scaled with reward magnitude. These results show distinct laminar organization of different functional signals in the SEF which constrain circuit-level models of visual performance control and guide inverse modeling solutions of EEG error- and feedback-related negativity.

Acknowledgement: This work was supported by R01-MH55806, P30-EY08126, and by Robin and Richard Patton through the E. Bronson Ingram Chair in Neuroscience.

25.24, 6:00 pm **Microcircuitry of visual performance monitoring in the supplementary eye field: Laminar distribution of visual processing under conflict** Steven P Errington[1](steven.p.errington@vanderbilt.edu), Amirsaman Sajad[1], Jeffrey D Schall[1]; [1]Vanderbilt Vision Research Center, Center for Integrative & Cognitive Neuroscience, Department of Psychology, Vanderbilt University

Being error prone, the context of visual behavior must be monitored to achieve goals. Previous work in monkeys performing a saccade countermanding task has demonstrated modulation of signals in the supplementary eye field in response to visual information and conflict between mutually incompatible visuo-motor plans. However, the laminar distribution of these signals is unknown. We present neurophysiological data from two monkeys collected using a linear electrode array during visual saccade countermanding task. Monkeys were rewarded for making a saccade to a visual target; however, in infrequent, random trials a stop signal appeared instructing the subject to cancel this pre-planned saccade. These stop signal trials engendered conflict between the competing GO and STOP processes. From 16 perpendicular penetrations, we isolated 293 neurons across all SEF layers. Significant modulation to a visual target was noted in 80 neurons, with a mean latency of 71 ± 20 ms. Spiking activity

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was concentrated in layers 2 to 5 and absent in layer 6. Visual neurons with wide spike widths were distributed throughout the cortex, but those with narrow spikes were primarily concentrated in layer 3. In trials associated with lower reward amounts neurons demonstrated higher visual responses, most pronounced in the latter period of the visual response. Significant modulation when monkeys had to withhold a pre-planned movement to a target was noted in 18 of these visual neurons, and in 50 neurons in total. These cells were primarily concentrated in layers 2, 3 and 5. Conflict-responsive neurons with narrow spikes (n=21) were located significantly more superficially than those with wide spikes (n = 29), U = 403.50, p=0.009. These findings further delineate the mechanisms of medial frontal cortex in performance monitoring. The contribution of laminar specific signals constrains circuit-level models of executive control and guide further inverse modelling solutions of visual performance event-related potentials.

Acknowledgement: This work was supported by R01-MH55806, P30-EY08126, and by Robin and Richard Patton through the E. Bronson Ingram Chair in Neuroscience.

25.25, 6:15 pm **Dynamic remapping in Monkey Frontal Eye Field preserves a retinotopic representation during visual search, then compresses space toward the search target.** Daniel K Wood[1](daniel.wood@northwestern.edu), Pavan Ramkumar[1, 2], Joshua L Glaser[1, 3], Patrick N Lawlor[1], Konrad P Körding[3], Mark A Segraves[1]; [1]Neurobiology Dept., Northwestern University, [2]Balbix Inc, [3]Bioengineering and Neuroscience Depts., University of Pennsylvania

In primates, the Frontal Eye Field (FEF) controls saccades used to search the environment and foveate search targets. The receptive fields (RFs) of FEF neurons are not always statically fixed to a retinotopic location. Rather, they predictively remap to conform to the future fixation position just before a saccade begins. Two modes of perisaccadic remapping have been observed. In forward remapping, the RF jump follows a vector parallel to the upcoming saccade. In convergent remapping, the RF is pulled toward the endpoint of the upcoming saccade. Here, we ask what adaptive purpose RF remapping may serve for visual search behavior, characterized by exploratory and exploitative saccades. Exploratory saccades are high latency, low velocity saccades performed in a sequence to gather visual information, while exploitative saccades are low latency, high velocity, individual saccades performed to foveate the search target. We hypothesize that forward remapping is adaptive for exploratory saccades because it allows for a retinotopically accurate preview that will facilitate potential discovery of targets and planning of upcoming movements. Likewise, we hypothesize that convergent remapping occurs during exploitative saccades, and that this momentarily enhances visual representation around the target. To test this, we recorded from FEF neurons while monkeys searched for a target (gabor patch) embedded in a Perlin noise background. The monkeys were trained to ignore visual probes that were rapidly flashed at random locations during the search behavior. The visual responses elicited by the probes allowed us to infer RF location continuously throughout natural search behavior. We observed forward remapping around exploratory saccades and convergent remapping around exploitative saccades. This effect was strongest in cells that showed delay period activity during a memory guided saccade task. These results suggest that the dynamic reshaping of visual space in FEF facilitates different saccadic strategies.

Acknowledgement: NIH (NEI)

25.26, 6:30 pm **Cortical Control of Eye Movements in Natural Tasks** Jessica E Goold[1], Wonil Choi[2], John M Henderson[1,3]; [1]Center for Mind and Brain, University of California, Davis CA, USA, [2]Department of Psychology, GIST, Guangju, South Korea, [3]Department of Psychology, University of California, Davis CA, USA

Natural active visual tasks require fine-grained management of saccadic eye movements. A critical question, therefore, involves how the brain controls eye movements in natural tasks and whether this control differs for different tasks. Neural correlates of eye movements have been found in multiple cortical regions, most prominently frontal eye fields (FEF), supplementary eye field (SEF), and intraparietal sulcus (IPS). However, most research investigating this network has focused on single-saccade tasks, and little is known about its role in natural settings. The present study investigated this issue using scene viewing, reading, and two control conditions. Participants in an MRI scanner with eye-tracking were presented with scene photographs, natural text paragraphs, pseudo-font paragraphs, and random-string paragraphs. Participants freely viewed the scenes, read naturally in the text condition, and moved their eyes as if they were reading in the two pseudo-reading conditions. Multi-voxel pattern analysis was used for fine-grained analysis of the fMRI signal in regions of the eye movement control network. We found that activation patterns in all regions of the network differentiated between natural reading and scene viewing and critically also differentiated between natural reading and the two pseudo-reading conditions. These results suggest that the eye movement network reflects more than simple saccade generation and are consistent with the hypothesis that the network encodes information about category and meaning consistent with the cognitive system with which is it interfacing.

Acknowledgement: NEI/NIH R01EY027792

Saturday Afternoon Posters

Spatial Vision: Models

Saturday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

26.301 **Aberrant Population Receptive Fields in Albinism** Ethan J Duwell[1](eduwell@mcw.edu), Melissa A Wilk[2], Jed Mathis[3], Joseph Carroll[4], Edgar A DeYoe[3]; [1]Biophysics, Medical College of Wisconsin, [2]HudsonAlpha Institute for Biotechnology, [3]Radiology, Medical College of Wisconsin, [4]Ophthalmology, Medical College of Wisconsin

During development, retinal hypo-pigmentation in albinism leads to aberrant decussation of temporal retinal afferents at the optic chiasm thereby producing partially superimposed representations of opposite hemi-fields in visual cortex. Previous studies of neuronal mis-wiring in achiasmic patients found that population receptive fields (pRFs) in visual cortex were often split into two separate regions typically positioned at mirror image locations across the vertical meridian (Hoffmann et al., 2012). However, such dual-pRFs have not been reported or quantitatively modeled in albinism. We used conventional ring and wedge stimuli with fMRI at 3T to map cortical retinotopy and model individual voxel pRFs throughout the visual hierarchy in 5 albinism subjects. Our hypothesis was that voxel responses within hemi-field overlap regions would be fit best by dual rather than single gaussian models. This is consistent with the qualitative observation that single voxel responses in overlap zones often display twice the number of expected response peaks to rotating wedge stimuli. To test our hypothesis, we first used monocular, left and right hemi-field ring stimuli to identify cortical zones with overlapping representations of opposite hemifields. Consistent with previous reports, all albinism subjects exhibited aberrant regions of hemi-field overlap. Voxel responses throughout visual cortex were fit with both single and dual gaussian pRF models. To compare the model fits, we used the residual sum squared error and the number of model parameters to compute Akaike's information criterion. Of nearly 11,000 voxels successfully modeled, over 1000 were fit best by the dual pRF model, and the majority of these fell within overlap zones. In contrast, of ~7,000 voxels in non-overlap zones the majority were fit better with a single gaussian model. These results provide quantitative evidence that gross aberrations of cortical retinotopic organization in albinism are further reflected in aberrant pRF structure at the level of single voxels.

Acknowledgement: R01EY024969

26.302 **Optimizing stimulation protocols for prosthetic vision based on retinal anatomy** Michael Beyeler[1](mbeyeler@uw.edu), Devyani Nanduri[2], James D Weiland[3], Ariel Rokem[1], Geoffrey M Boynton[1], Ione Fine[1]; [1]University of Washington, [2]University of Southern California, [3]University of Michigan

Introduction: The field of electronic retinal prostheses is developing rapidly, with three varieties of retinal prostheses approved for commercial use and several others in development. However, many of these devices stimulate retinal axon fibers as well as cell bodies, leading to elongated and poorly localized percepts that severely limit the quality of the generated visual experience (Nanduri et al. 2011). We previously developed a computational model that describes these distortions and predicts a patient's perceptual experience for any electrical stimulation pattern (Horsager et al. 2009, Nanduri et al. 2012, Beyeler et al. 2017). However, improving the design of neuroprosthetic devices requires a solution to the inverse problem: What is the optimal stimulation protocol to elicit a desired visual percept? Methods: A simulated Argus II epiretinal prosthesis (Second Sight Medical Products Inc.) implant was placed on top of a map of ganglion axon pathways (Jansonius et al. 2009), designed to mimic known retinal anatomy, and used to generate predictions about the shape and location of visual percepts. The location and orientation of the implant with respect to the fovea and the optic nerve head was estimated using fundus images. The resulting predictions closely matched reported percepts when subjects were asked to trace the phosphenes generated by single electrodes on a touch screen. These synthetic percepts were then used as features in a regularized regression optimized to find stimulation protocols that would minimize perceptual distortions of Snellen letters. Results and Conclusions: Percepts produced with the optimized stimulation protocols partially compensated for the perceptual distortions caused by axonal stimulation: letters were much more recognizable than those generated using conventional protocols. Future work will include validating these results in patients and developing more sophisticated machine learning methods that can compensate for spatiotemporal distortions across a wider range of implants.

26.303 **Title: Convolutional Network Approach to Modelling Allocentric Landmark Impact on Target Localization** Sohrab Salimian[1,3](salimian@my.yorku.ca), Richard P. Wildes[1,4], John D. Crawford [1,2]; [1]Center for Vision Research: Vision Science to Applications Program (VISTA), [2]Departments of Psychology, Biology, Kinesiology and Health Science, York University, Toronto, ON, Canada, [3]Department of Biology York University, Toronto, ON, Canada, [4]Center for Vision Research, Department of Electrical Engineering and Computer Science, York University, Toronto, ON, Canada

A critical question in visual processing is the degree to which egocentric and allocentric reference frames are utilized during target localization. For example Li et al (2017) tested their contributions using the cue conflict task on macaque monkeys, where the monkeys were presented with a target and an allocentric landmark. The landmark was then masked and shifted (or not shifted). During the shift paradigm the monkeys' final gaze position was siginificantly shifted towards the virtually shifted location of the target in allocentric coordinates. In the current work we attempted to model these results by utilizing a convolutional network (ConvNet) with a spatial transformer module. This model inputs a binary image containing a target localized at a particular spatial location as well as an allocentric landmark represented as the intersection of vertical and horizontal lines. It outputs a vector anchored at the (0,0) position on the image matrix, corresponding to the position on the array where the target has been calculated to lie in. The network achieves this through multilayer processing that begins by estimating and applying an affine transformation that accounts for differences in the target vs landmark coordinates, followed by convolution and regression for target localization. The affine transformation is learned through the spatial transformer which takes the image and applies the reverse of the transformations and then feeds the output to the convolutional and regressional layers (Jaderberg et al 2015). The model's outputs is in agreement with the findings in Li et al (2017): As the landmark is shifted away from the target, the network's choice is also shifted away from the target position. Future work will look to increase robustness in terms of target localization with respect to mutliple allocentric landmarks and to modify the model's architecture to include hand-crafted components to increase precision.

Acknowledgement: NSERC and VISTA

26.304 **Spatial Summation in Noise** Yu-Hsin Yeh[1](b01b01057@g.ntu.edu.tw), Chien-Chung Chen[1,2], Christopher W Tyler[3,4]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Center for Neurobiology and Cognitive Science, National Taiwan University, Taipei, Taiwan, [3]Smith-Kettlewell Eye Research Institute, San Francisco ,California, USA, [4]Division of Optometry and Visual Science, School of Health Sciences, City University, London, UK

We investigated the effect of background noise on visual spatial summation. We measured the contrast detection threshold of a Gabor target with or without the presence of a white noise mask (4' pixel size) which varied in luminance contrast. The targets were Gabor patterns placed at 3-degree eccentricity to the left or the right of the fixation point and elongated along an arc of the same radius to ensure that every point on the long axis of the stimuli was equal-distance from the fixation. We used a spatial two-alternative forced choice (2 AFC) paradigm, in which the task of an observer in each trial was to indicate whether the target was presented to the left or the right of the fixation. We used the PSI dynamic staircase procedure to measure the threshold at 75% accuracy. Each threshold reported was an average of 4 repeat measurements. When the target size was small

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(< 36′ half-high full width, HHFW), the detection threshold decreased with target size with slope -1 on log-log coordinates, and then further decreased with slope -1/2 till around 72′-100′ HHFW, defining the range of attentional summation (Tyler & Chen, 2001). For the same observer, the summation curves at different noise contrasts were shifted copy of each other. The target threshold was constant for noise level up to -26dB (target HHFW=14′) or -18 dB (all other target sizes), then increased linearly with noise contrast on log-log coordinates. Since the "elbow" of the target threshold vs. noise intensity function indicates the level of the equivalent internal noise, our result suggests that while the internal noise increases with target size in the full summation range (up to 36′ HHFW), it remains constant across target size in the attentional summation range.

Acknowledgement: MOST106-2410-H-002-074-MY2

26.305 **Variable slope of the psychometric function for different spatial frequencies measured by the Tuebingen Contrast Sensitivity Test** Tim Schilling[1](tim-tobias.schilling@uni-tuebingen.de), Alexander Leube[1], Arne Ohlendorf[1,2], Siegfried Wahl[1,2]; [1]Institute for Ophthalmic Research, Eberhard Karls University Tuebingen, Tuebingen, Germany, [2]Technology & Innovation, Carl Zeiss Vision International GmbH, Aalen, Germany

Introduction: The threshold contrast and the slope of the psychometric function can be determined by using computer-based stimulus presentations and an adaptive staircase, like the TuebingenCSTest (TueCST). The TueCST assesses contrast sensitivity with high repeatability and reliability, using a fixed slope. The slope of the psychometric function is the measure of change in performance with changing stimulus intensity, which reflects the variability of the estimated threshold contrast. The slope relies on several factors, like finger errors, eye artefacts due to e.g. blinks, observers' attention or motivation. The aim of the study was to estimate individual slopes for each participant in order to increase the accuracy of the threshold contrast assessment. Methods: In this study, the slope of the psychometric function was estimated with the TueCST, using 250 trials for different spatial frequencies in eight experienced (0.5, 1.5, 3, 6 and 12 cycle per degree – cpd) and eight naïve participants (1.5, 3, 6, 12, 20 and 30cpd). The stimulus was a Gabor Patch grating with four possible orientations to identify. Results: Repeated ANOVA returned a significant effect for spatial frequency in experienced participants ($F(4,28)=30.9$, $p< 0.001$, $\omega^2=0.78$) and naïve participants ($F(5,35)=62.4$, $p< 0.001$, $\omega^2=0.88$). Largest slopes were estimated for lower spatial frequencies (≤6cpd) and smallest slopes for higher spatial frequencies (≥12cpd) in both subgroups. In naïve participants, the threshold contrast was significantly lower for a first measurement with a fixed slope compared to the second measurement for slope estimation ($p< 0.05$). Comparing the slopes of naïve and experienced participants, there was no significant difference ($p=0.7$). Conclusion: When using the TueCST, the estimated slopes of the psychometric function showed a difference between higher and lower spatial frequencies. These results revealed that naïve participants were sufficiently trained after one measurement with the TueCSTest, resulting in indistinguishable slopes between naïve and experienced participants.

26.306 **Inferring the shape of decision variable distributions from psychometric functions** Johannes Burge[1,2,3]; [1]Psychology, University of Pennsylvania, [2]Neuroscience Graduate Group, University of Pennsylvania, [3]Bioengineering Graduate Group, University of Pennsylvania

The psychometric function is a mainstay of psychophysics and behavioral neuroscience research, and signal detection theory (SDT) is a widely used tool for analyzing and interpreting psychometric data. SDT is perhaps most important for inferring the statistical properties of decision variables that are posited by the theory to underlie behavioral performance. Decision variables are usually most conveniently modeled as being Gaussian distributed. In many cases, however, there are theoretical and empirical reasons to assume that decision variables are non-Gaussian. How do non-Gaussian decision variables impact the shape of the psychometric functions collected in behavioral experiments? And how does spatial (or temporal) uncertainty, an important factor in many target detection tasks, complicate the ability to determine the shape of the decision variable distribution from the shape of the psychometric function? Here, with a series of computational analyses, we demonstrate how non-Gaussian decision variable distributions determine the shape of psychometric functions in the presence (or absence) of arbitrary levels of uncertainty. We also show how well the shape of the psychometric function can be used to infer the shape of the decision variable distribution in the presence (or absence) of arbitrary levels of spatial or temporal uncertainty. The results provide a guide for interpreting the results of psychophysical experiments.

26.307 **The Contrast Sensitivity Function in children: Bayesian adaptive estimation using QUEST+** Mahtab Farahbakhsh[1](m.farahbakhsh.16@ucl.ac.uk), Tessa M Dekker[1], Pete R Jones[1,2,3]; [1]Institute of Ophthalmology, University College London (UCL), UK., [2]NIHR Moorfields Biomedical Research Centre, London, UK., [3]Division of Optometry and Visual Science, School of Health Sciences, City University of London, London, UK.

In clinical vision-science, we currently lack a robust, child-friendly measure of the Contrast Sensitivity Function (CSF). Traditional psychophysical techniques (e.g., Transformed Staircases; Method of Constant Stimuli) are too slow, and are prone to be misled by lapses. Recently, Bayesian adaptive estimation has been suggested as a potential solution (e.g., the "qCSF"). Here, we evaluate a novel implementation of Bayesian adaptive CSF estimation, using QUEST+. We implemented two versions of the QUEST+ method: (1) with prior assumptions about the shape of CSF, and (2) without prior assumptions about the shape of CSF (i.e., flat prior assumption). To assess our test's accuracy, we asked 41 4-14-year-old Children and 13 adults to complete the two versions of our QUEST+ CSF tests and an adaptive staircase CSF test. There was a good correspondence in contrast sensitivities (i.e., the peak of the CSF curve) measured with QUEST+ and the staircase. In addition, there were no significant differences between estimates from the two QUEST+ methods. In a second experiment, we assessed test-retest reliability by asking 18 6-10-year-old children and 15 adults to complete each test twice. All methods exhibited similar test-retest reliability as indicated by Bland-Altman analyses. Finally, we performed an age comparison of contrast sensitivity across children. This revealed a ~1.5 dB/year increase between 4-14 years. However, this developmental effect was small relative to the individual variability across subjects (i.e., between-subjects, contrast sensitivity ranged from 10 to 44 dB). These results show that it is feasible to obtain accurate, fast, and reliable measures of the CSF in children using the QUEST+ method. This offers potential improvements over gold standard tests currently used for diagnosis and treatment outcome of childhood eye disease.

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26.308 **Decision-Variable Correlation: An Extension of SDT** Wilson S Geisler[1,2](w.geisler@utexas.edu), Stephen Sebastian[1,2]; [1]Center for Perceptual Systems, University of Texas at Austin, [2]Department of Psychology, University of Texas at Austin

A straightforward extension of the signal detection theory (SDT) framework is described and demonstrated for the two-alternative identification task. The extended framework assumes that the subject and an arbitrary model (or two subjects, or the same subject on two occasions) are performing the same task with the same stimuli, and that on each trial they both compute (in effect) values of a decision variable. Thus, their joint performance is described by six fundamental quantities: two levels of intrinsic discriminability ("d-prime"), two values of decision criterion, and two decision-variable correlations, one for each of the two categories of stimuli in the task. Decision-variable correlations (DVCs) provide increased power for testing models and for characterizing individual differences, and do not require a special experimental design (e.g., they can be computed from existing data). The extended framework was developed for analyzing trial-by-trial performance in vision experiments with natural stimuli, but it should be widely applicable in behavioral and neurophysiological studies of perception and cognition. We demonstrate the framework for the well-known task of detecting a Gaussian target in white noise and make several theoretical and experimental discoveries: (1) subjects' DVCs are approximately equal to the square root of their efficiency relative to ideal (in agreement with the prediction of a popular class of models), (2) between-subject and within-subject (double-pass) DVCs increase with target contrast and are greater for target-present than target-absent trials (rejecting many models), (3) model parameters can be estimated by maximizing DVCs between the model and subject, (4) a model with a center-surround template and a specific (modest) level of position uncertainty predicts the trial-by-trial performance of subjects as well (or better) than presenting the same stimulus again to the subjects (i.e., the double-pass DVCs, which are as high as 0.7). We conclude that measuring DVCs can be of considerable value.

Acknowledgement: NIH grants EY11747 and EY024662

26.309 **Towards a computational observer model of perceptual performance fields** Eline R Kupers[1](eline.kupers@nyu.edu), Marisa Carrasco[1,2], Jonathan Winawer[1,2]; [1]Department of Psychology, New York University, New York, USA, [2]Center for Neural Science, New York University, New York, USA

Background: Visual performance depends on polar angle when eccentricity is held constant; on many psychophysical tasks observers perform best on the horizontal meridian, worst on the upper vertical, and intermediate on the lower vertical meridian. This variation in performance with polar angle, called 'performance fields', can be as pronounced as that of doubling the target eccentricity. The cause of these asymmetries in performance is largely unknown. Goal: To investigate the extent to which factors in the eye contribute to performance fields, we implemented a first stage computational observer model focusing on the front-end of the visual system. Methods: The stimuli were static Gabor patches at 4.5º eccentricity, 4 cpd, 1º SD, oriented 20º clockwise or counterclockwise from vertical, with contrast varying from 0% to 20%, presented for 200 ms. Our computational observer model began with the full spectral representation of the stimulus, which was jittered by small fixational eye movements (tremor and drift), and transformed by the human optics and spatial and spectral sampling of the cone mosaic. The time-varying 2D array of cone absorptions was used as input to a linear support vector machine classifier, which performed a 2AFC discrimination (clockwise / counterclockwise). We asked how changes in defocus and cone density affect model performance. Results: To account for the nearly doubling of thresholds for upper vertical compared to horizontal meridian, as observed psychophysically on the same task, our computational observer model would require either an increase of ~5 diopters (D) of blur or a 50% reduction in cone density. Because cone density at 4.5 deg eccentricity varies only by about 10% across polar angles, and blur at 4.5 deg is typically less than ~0.25 D, these factors account for a small fraction of performance fields. Substantial additional asymmetries must arise in retinal or cortical processing.

Acknowledgement: NEI R01 EY027401

26.310 **Prior Experiences Influence Target Localization in Centroid Tasks** Jocelyn K Lopez[1](jklopez1@uci.edu), Jordan Ali Rashid[1], Charles C Chubb[1]; [1]University of California, Irvine

This project investigated how centroid estimates depend on the recent experience of the participant in the task. Stimuli were brief clouds comprising 18, barely visible dots, and on each trial the participant strove to mouseclick the centroid. A double- pass procedure was used: that is, each participant went through exactly the same set of stimulus sequences twice. The data are well-described by a model in which the response on a given trial is a weighted sum of the centroid of the current stimulus and the previous response location. Setting the mixture parameter to zero yields a nested model in which the current response is immune to influence from the previous response. A likelihood-ratio rejects this nested model supporting the claim that the current response is influenced significantly by the previous response. Since the double-pass procedure provides a model-free estimate of intrinsic process noise, it is a tool for model rejection using a least-squares criterion. Specifically, if the noise estimate provided by the double-pass procedure is significantly less than the noise estimate derived from the deviation of the model predictions from the data, then the model is rejected. In the current instance, the residual noise in the fit provided by the mixture model is very close to the model- free estimate of the response noise estimated from the double-pass procedure. We conclude that the mixture captures all of the structure in the data.

Acknowledgement: UCI Undergraduate research opportunities program

26.311 **MaxFind: an efficient method for psychological scaling of large stimulus sets** Isamu Motoyoshi[1](imotoyosi@gmail.com), Saya Kashiwakura[2]; [1]Department of Life Sciences, The University of Tokyo, [2]Department of Integrated Sciences, The University of Tokyo

Increasingly, studies on the perception of objects, materials, and faces employ a large number of natural images to ask observers for various perceptual and emotional attributes such as shape, softness, and attractiveness. To measure the subjective intensity of such attributes, many studies have used magnitude estimation - or rating -, but rating is often an unstable measure. Thurstone's classic paired comparison is based on comparative judgments but it requires a large number of trials as the stimulus set becomes large. Here, we combine maximum-likelihood algorithms in a novel psychophysical procedure and propose an experimental protocol of comparative judgments that can order and scale the subjective intensity of stimuli using only a small number of trials. In this protocol, (1) observer views a list of M stimuli taken from N stimuli, and repeatedly choose the stimulus that elicits maximum subjective response along a given dimension (e.g., the most attractive) until the last stimulus remains. (2) On each trial, stimuli in the N x N comparison matrix are sorted according to a psychological scale constructed from PSE and JND as estimated by logistic regression analyses. (3) The next M stimuli are sampled such that responses will be collected only for pairs for which the expected response ratio is close to 0.5. Numerical simulations demonstrate that our method, for M larger than 8, can estimate psychological scale with only ~1.3 x N responses (e.g., ~130 responses for 100 stimuli). Psychophysical experiments confirmed that the method can quickly estimate the contrast response function to gratings and the perceived glossiness of naturalistic objects. This method would be useful for characterizing human judgements along many psychological dimensions, especially those with no physical correlate such as emotional and social attributes

Acknowledgement: JSPS KAKENHI JAPS15H05916 and JAPS15H03461

26.312 **The HCP 7T Retinotopy Dataset: A new resource for investigating the organization of human visual cortex** Noah C Benson[1](nben@nyu.edu), Keith W Jamison[2], An T Vu[3,4], Jonathan Winawer[1,5], Kendrick N Kay[6]; [1]Department of Psychology, New York University, [2]Department of Radiology, Weill Cornell Medical College, [3]Center for Imaging Neurodegenerative Diseases, University of California San Francisco, [4]San Francisco Veteran Affairs Health Care System, [5]Center for Neural Science, New York University, [6]Department of Radiology, University of Minnesota

Visual field maps cover a large fraction of the cortical surface, and can be measured using fMRI retinotopic mapping procedures (Engel et al., 1997, Cereb Cortex 7:181). One of the datasets collected in the Human Connectome Project (Van Essen et al., 2013, NeuroImage 80:62) consisted of scanning 183 human subjects in a retinotopic mapping experiment using high-field (7T) fMRI. Here, we describe the experimental paradigm and provide results of population receptive field (pRF) analyses of these data. Our analyses include both pRF results from individual subjects as well as those obtained after averaging fMRI time-series across subjects at anatomically-aligned locations on the cortical surface and in subcortex. The group-average results reveal robust visually-driven signals across much of the brain, including occipital, temporal, parietal, and frontal cortex as well as subcortical areas. Based on these results, we construct a new atlas of retinotopic organization for early visual areas, improving on a previous atlas developed from a smaller set of subjects (Benson et al., 2014, PLoS Comput Biol 10:e1003538). The atlas includes pRF position (polar angle and eccentricity) as well as pRF size, which marks a novel contribution to the field. We will be publicly releasing the new retinotopic atlas and the complete pRF results for the group-average and all individual subjects. We believe these resources will be of great interest to the vision community for several reasons. First, the group-average data and atlas predictions can be used to accurately estimate a subject's retinotopic organization based on their cortical anatomy alone. Second, the dataset serves as a state-of-the-art characterization of baseline retinotopy measurements in neuro-typical subjects. Finally, this dataset enables characterization of individual differences in retinotopic organization throughout cortex on a scale that has been previously impossible.

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Color and light: Surfaces, illuminants, materials

Saturday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

26.313 **Influence of natural illumination changes on hue statistics in natural scenes** Kinjiro Amano[1](kinjiro.amano@manchester.ac.uk), Sérgio M. C. Nascimento[2]; [1]School of Electrical and Electronic Engineering, University of Manchester, UK, [2]Centre of Physics, Gualtar Campus, University of Minho, Portugal

Surface color appearance is susceptible to changes in lighting. Colorimetric properties in art paintings under artificial light sources are markedly influenced by a change in illuminant from e.g. a standard daylight with correlated color temperature (CCT) 6500 K to a fluorescent or LED lamp with lower CCT of 4000 K (Amano et al., ICVS 2017). It is unclear, however, whether the natural lighting changes in the environment have a similar effect on colorimetric statistics, and whether they are relevant to color vision mechanisms. To address these questions, four time-lapse hyperspectral radiance images of natural scenes were analyzed colorimetrically. The illumination on the scenes was natural daylight of CCT ranging from 3000 K to 7500 K. The natural scenes included distant views of houses and mountains, a rock formation, and the terrace of a house. Scenes were acquired in Portugal between noon and sunset in July and October. Distributions of chroma values were analyzed with hue angle in CIELAB space and in a scaled MacLeod-Boynton space (Webster et al., J Opt Soc Am A, 2000) with a reference illuminant D65. The profiles of the distributions varied across the scenes and the natural illuminants. But the higher chroma values clustered at constant hue angles in both color spaces, corresponding to approximately blue-yellow direction. Even when the reference illuminant was replaced with each of the global illuminants derived from a neutral surface in a scene, the hue angles for higher chroma values were less affected, although the chroma values increased a little with CCTs. These results suggest that natural illumination changes may influence colorimetric attributes in different ways. Thus, hue may be more robust than chroma in the scenes tested, and contributions to the blue-yellow mechanism may be more critical than to the red-green.

Acknowledgement: EP/F023669/1, GR/R39412/01, EP/B000257/1, and EP/E056512/1

26.314 **Influence of the diffuseness of illumination on color appearance** Yoko Mizokami[1](mizokami@faculty.chiba-u.jp), Wataru Nozaki[2], Hirohisa Yaguchi[3]; [1]Department of Imaging Sciences, Graduate School of Engineering, Chiba University, [2]Graduate School of Advanced Integration Science, Chiba University, [3]Chiba University

The appearance of object surface could be largely influenced by lighting conditions and object materials. Our previous study showed that the diffuseness of lighting influenced the appearance of the glossiness and the roughness of an object in particular (VSS 2017, ICVS 2017). Here, we investigated the influence of the diffuseness on color appearance. We examined how the color appearance of object surface was influenced by the diffuseness of lighting in miniature rooms. We used two miniature rooms illuminated by a diffused light and a direct light, respectively and placed a test sample at the center of each room. Test samples were square-shape patches with wavy striped surface. Both glossy and matte surface materials with five colors were prepared for the samples. We tested white and reddish illumination conditions. In addition, a viewing condition which limited the field of view to a test patch so that no surrounding information was available was tested. An observer judged the color appearance of a color sample under each lighting condition by selecting a corresponding color from a Munsell color chart placed in a separate viewing box illuminated uniformly by the same color as the test room. The results of corresponding color for test samples were similar in both diffused and direct lighting conditions even if the luminance distribution of the surface was largely changed depending on the diffuseness of lighting and the surface glossiness. This indicates that the color appearance of samples that we tested was quite stable. There was little difference in color appearance of samples in the limited viewing condition. These results suggest that we are able to compensate the change in surface appearance and recognize a surface color.

Acknowledgement: JSPS KAKENHI JP16K00368 and JP16H01663

26.315 **The neighbouring chromaticity influences the judged intensity of illumination** Eli Brenner[1](e.brenner@fbw.vu.nl), Ruben C Pastilha [2], Sérgio Nascimento[2]; [1]Department of Human Movement Sciences, VU University Amsterdam, [2]Centre of Physics, Gualtar Campus, University of Minho

To identify surface properties independently of the illumination the visual system must make assumptions about the statistics of scenes. Are assumptions about the intensity of the illumination independent of assumptions about its chromaticity? To find out, we asked participants to judge whether test patches within three different sets of surrounding surfaces were white or grey. Two sets were matched in terms of their mean luminance, maximal luminance, and variability in luminance, but differed in how luminance and chromaticity were associated: the highest luminance was either associated with colourful surfaces or with achromatic ones. We found that test patches had to have a higher luminance to appear white when the highest luminance in the surrounding was associated with colourful surfaces. This makes sense if one considers that a perfectly white surface reflects all of the light falling on it, while being colourful implies that a surface only reflects part of the light that falls on it, meaning that the illumination must have a higher luminance. In the third set, the highest luminance was associated with the same colourful surfaces, but the mean luminance was lower. Despite the constraints on the illumination being identical to those of the other set with high luminance chromatic surfaces, test patches did not have to have as high luminance to appear white for the third set. Considering the layout of the surfaces in the surrounding revealed that test patches did have to have the same high luminance if the high luminance colourful surfaces were adjacent to the target patch. Thus, the assumptions about the possible illumination are applied locally. A possible mechanism is relying on the contrast within each type of cone: for a surface to appear white it must stimulate each of the three kinds of cones substantially more than do any neighbouring surfaces.

26.316 **Adaptation and perceived contrast in natural vs wide-color-gamut lighting** Ivana Ilic[1](ivanailic@nevada.unr.edu), Lorne Whitehead[2], Yoko Mizokami[3], Michael Webster[1]; [1]University of Nevada, Reno, [2]University of British Columbia, [3]Chiba University

The new generation of wide color gamut lighting and displays substantially increases the range of color contrasts observers may be exposed to. For example, a typical wide gamut illuminant can increase the range of reddish-greenish contrasts by roughly 30%. The perceptual consequences of this exposure remain largely unexplored. In a previous study, we examined how observers adapt to the gamut change simulated by a random temporal sequence of uniform chromaticities, chosen to simulate the same Munsell surfaces when viewed under a wide gamut illuminant or equivalent black body spectrum. In the present work we extended this to more naturalistic viewing conditions, in which the set of colors was shown as random spatial variations within images. The images were Mondrians composed of a dense collage of rectangles, with colors drawn from 36 hue angles uniformly spanning the LM vs S chromatic plane and randomly varied in luminance. Observers simultaneously adapted to rapid sequences of the same surface sets under the two illuminants, on the left and right side of a CRT monitor, and then adjusted the relative LM contrast of pairs of test images to match their perceived contrast. Adaptation to the higher LM contrast images reduced the perceived contrast in the Mondrians for a range of test contrasts, including the contrasts of the adaptors. These effects are consistent with the results observed for the sequential adaptation, and further suggest that exposure to the wider gamut introduced by artificial lighting and displays is likely to induce "artificial" states of adaptation that alter the perceived colorfulness of images.

Acknowledgement: EY010834

26.317 **Illumination Colour, Texture, and the Appearance of Glow** Khushbu Y Patel[1](khushbup@my.yorku.ca), Richard F Murray[1]; [1]Department of Psychology and Centre for Vision Research, York University

Even under restricted viewing conditions (e.g., monocular, stationary) people usually recognize that an LCD screen emits light instead of reflecting incident light. In previous experiments, we found that colour and texture were driving cues for glow detection with LCD screens. When a translucent, textured paper sample was placed in front of a

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computer screen, and the CIE xy chromaticity coordinates of the screen were matched to paper samples, participants were unable to differentiate between small patches of an LCD screen and real paper. Here, we hypothesize that the same realism can be achieved by matching the CIE xy chromaticity coordinates of the environment's lighting to the LCD monitor's white point. In a 9AFC task, observers viewed a 3x3 grid of nine 3.2 cm square apertures. Through one randomly chosen aperture, observers viewed a sample of translucent paper on an LCD screen, and through the other eight apertures, they viewed samples of opaque paper. The observer judged which aperture was light-emitting rather than reflective. Conditions 1 and 2 took place under beige ambient lights (CIE x=0.39; y=0.38). In these condition, the (1) luminance or (2) colour (CIE XYZ) of the translucent paper was matched to a randomly chosen paper sample. In condition 3, the lighting in the room was matched to the computer's white point (x=0.31, y=0.32) and the screen showed luminance-calibrated patches. Observers were significantly better at identifying the light-emitting patch in condition 1 than in conditions 2 and 3, but performance in the latter two was still above chance. We conclude that neither color matching screen display under normal room lighting or matching the chromaticity of the environment's lighting to an LCD screen is sufficient to eliminate cues to glow.

26.318 **#TheDress type of color ambiguity induced by T-shirt image based on physically-based rendering** Kai Shiromi[1](shiromi16@vpac.cs.tut.ac.jp), Higashi Hiroshi[1], Mohammad Shehata[1,2], Shinsuke Shimojo[2], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Biology and Biological Engineering, California Institute of Technology

Color ambiguity in the photo "#TheDress" has been considered as a special case due to its specific color distribution because only few other images turned out to induce similar effect. This study demonstrates "T-shirt" images to induce the similar effect by physically-based rendering with manipulating illuminant cue. Mitsuba-Renderer was used to generate the images of pink/gray striped T-shirts. Illuminant color was varied from white to greenish so that the reflected light from the pink and gray parts of the T-shirt become gray and green. Note that the same color reflection occurs when the "gray/green" T-shirt is illuminated by pinkish to white light. Thus without any illuminant cues, color constancy may fail. To confirm in the Exp.1, observers were asked to name the colors of each part of the pink/gray T-shirt image, rendered under various illuminant colors, displayed on black background. Exp.2 used the gray/green T-shirts image rendered under pinkish to white illuminant with achromatic floor and wall expected to work as a relevant illuminant cue. In Exp.3, the illuminant cue was given indirectly by a reference pink/gray T-shirt rendered under more pinkish illuminant, placed on the other side of the target image on black background. In Exp.1, color naming was stable and biased to either pink/gray or gray/green across individual observers, implying that there was a minimal illuminant cue inside of the T-shirt stabilizing the color percept, but that cue was used differently by individuals. Both in Exp. 2 and 3, cues modulated the color naming: less pink/gray and more gray/green responses were obtained, with color percept switched from pink/gray to gray/green within some observers. In conclusion, we found a systematic way 1) to generate other images to induce #TheDress-type effects and 2) to switch observers' color percept, providing a new approach to the underlying mechanisms of color ambiguity.

26.319 **A model of cortical color computation that explains key properties of perceptual color constancy** Michael E. Rudd[1](mrudd@uw.edu); [1]Department of Physiology and Biophysics, University of Washington

I previously proposed a model of lightness computation within the ventral stream of visual cortex and showed how the model explains quantitative lightness matching data (Rudd, Front. Hum. Neurosci., 2014; J. Electron. Imag., 2017). Here, I generalize that model to account for key properties of surface color perception, including instances of color constancy and constancy failures. In the cortical color model, information about local luminance and chromatic contrast is encoded in V1 by arrays of ON and OFF cells having center-surround receptive fields, and by double-opponent color cells having the standard L+M-/L-M+, L-M+/L+M-, ((L+M)+S-)/((L+M)-S+), and ((L+M)-S+)/((L+M)+S-) receptive fields. These six neural types encode local contrast along six half-axes in color space. The outputs of the six mechanisms are combined to create half-wave rectified, spatially-oriented, receptive fields that detect local spatially-directed changes in luminance and chromaticity (e.g. edges and gradients) within the retinal image. The neural edge and gradient detectors inherit the Naka-Rushton exponents of the ON, OFF, and double-opponent cells that form their inputs. Their outputs are subsequently log-transformed, then spatially integrated by V4 neurons, to compute surface color, coded in terms of directions in color space. The model predicts stable surface color percepts under changes in illumination, but is subject to constancy failures when spatial context is changed, as in simultaneous contrast. The model is consistent with data from single-cell recordings in V1, V2, and V4 (e.g. Smithson, Phil. Trans. Roy. Soc. B, 2005; Bushnell et al., J. Physiol., 2011), and with neuropsychological studies of patients with V4 damage (e,g. Kentridge et al., Neuropsychol., 2004), who exhibit failures of color constancy, while retaining the ability to local chromatic contrast discriminations. Furthermore, the model explains important quantitative aspects of lightness and color, including differences in the magnitudes of lightness and darkness induction and cube-root perceptual encoding of reflectance.

26.320 **Hue Flows and Shading Flows: emergent properties from their interaction** Steven W Zucker[1](steven.zucker@yale.edu), Emma Alexander[2], Daniel Holtmann-Rice[3], Benjamin Kunsberg[4], Roland Fleming[5]; [1]Computer Science, Yale University, [2]Computer Science, Harvard University, [3]Google, Inc, [4]Applied Mathematics, Brown University, [5]Psychology, University of Giessen

Visual cortex is organized around orientation information. This is well studied for luminance, from which many aspects of perceptual organization emerge, but not for color. Rather, spatio-spectral color information is normally associated with differences of averages (over wavelength and position), which leads to color opponency or appearance models (e.g., retinex). We here combine an orientation-based approach for intensity with one for color, and ask: what organizational properties emerge from the interaction between orientation information in the intensity domain with those in the color do- main. In summary, relationships between disparate heuristics about shape, color, lighting, texture, and material are revealed. We model intensity and hue variations geometrically, with gradient flows for each defining a direction (orientation) and a magnitude at every point. (Such flows correspond to measurements from orientationally-selective and double-opponent cells in visual cortex.) A previously described algorithm generates hue flows that are either parallel or transverse to shading flows; we now extend those results to the magnitude domain. We define relative hue frequency H: intuitively, how many cycles hue rotates through as luminence traverses from black to white, with saturation fixed. It generalizes observations, such as slow luminance gradients likely denote surface curvature or shadows, to include the co-variation of color. The implications are non-trivial. Our main result is that three natural domains emerge. In arbitrary units, (i) when hue frequency $H \approx 1$ the well-known 'color-shading effect' arises when the flows are parallel; this implies comparable color-luminance changes. (ii) When $H < 1$ a 'color- lighting effect' arises; color changes more slowly than luminance; and (iii) when $H > 1$ a 'color-texture effect' arises. New displays illustrate these domains for random surfaces, and all are confirmed with a standard depth- comparison task. Neurally plausible implementations of these computations are easily constructed.

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26.321 **Visual perception of liquids in motion** Matjaz Jogan[1](m-jogan@its.jnj.com), Jeffrey Martin[1]; [1]Johnson and Johnson

Viscosity of liquids can be readily perceived by our sense of vision. In this work we studied human perception of viscosity of liquids in motion. We measured the Weber fractions and estimated the perceptual bias due to a change in appearance. Stimuli were videos of Newtonian silicone oils that were pumped from a dispenser and landing on an inclined surface. There were 21 calibrated oil samples in total. Polydimethilsiloxane viscosity standards and a rheometer were used to achieve the target viscosities. Observes participated in a two-alternative forced choice task. In each trial they observed a reference and a test video and had to state in which

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video the liquid looked thicker. The responses from two separate sessions were used to determine the Weber fractions at five reference viscosities for i) transparent (N=57) and ii) opaque (N=57) stimuli. In a third session, reference stimuli were opaque and test stimuli were transparent (N=110). Responses from this session determined the perceptual bias due to change in appearance. Reference viscosities ranged from 500 to 16,000 centipoise (cP), and each observer saw each of the unique reference/test pairs once. Psychometric functions were fit to total data from all observers. Weber fractions were approximately 0.6 for medium thickness, but showed an increase for low (500 cP) and high (>3,500 cP) viscosities. Visual appearance of the liquids modulated how thick they looked. At low viscosity, opaque liquids appeared up to two times more viscous than transparent liquids. This bias got proportionally smaller as the thickness of the reference increased. At the highest reference viscosity (16,000 cP), opaque liquids appeared slightly less (1,660 cP) viscous than transparent liquids. Our results suggest that perception of viscosity is modulated by visual appearance, and particularly so in the range where discrimination is poor.

26.322 **The misperception of opacity, reflectance, and 3D shape** Phillip J Marlow[1](phillip.marlow@sydney.edu.au), Barton L Anderson[1]; [1]School of Psychology, University of Sydney

In order to recover scene properties, the visual system is confronted with disentangling the contributions of the light field from material properties and surface geometry. We previously proposed that the visual system uses the covariation of intensity and surface orientation to distinguish opaque and translucent surfaces. This covariation should be high for opaque surfaces and low for translucent materials, and stronger for convexities than for concavities (which can be dominated by vignetting and inter-reflections). Here, we show it is possible to induce dramatic misperceptions of the opacity, shape, and reflectance of Lambertian surfaces by simply varying the dominant illumination direction of the light field. A bumpy plane with Lambertian reflectance was rendered in either a diffuse (Ganzfeld) or natural light field. The orientation of the light field, and the albedo and relief of the bumpy plane, were parametrically varied. Observers matched the material appearance of each surface by adjusting the sub-surface scattering and specular reflectance parameters of a cube that was rendered in a different natural light field. The results show that the Lambertian surface in oblique illumination appears opaque and matte, whereas the matches for the same surface in frontal or diffuse illumination were very translucent and glossy. We then assessed the contributions of the convexities and concavities on perceived shape and material properties. Our results show that the perceived shape of the concavities appears to depend on information derived from the convexities, but the perceived reflectance and opacity depended on information derived from both; the perception of translucency is strongest when intensity covaries with relief depth rather than surface orientation. These results show that the perception of opacity, reflectance, and 3D shape can be dramatically affected by the light field, and provide new insights into the information used to compute these scene attributes.

26.323 **Does geometric sharpness affect perception of translucent material perception?** Bei Xiao[1](bxiao@american.edu), Shuang Zhao[2], Ioannis Gkioulekas[3], Wenyan Bi[1], Kavita Bala[4]; [1]American University, Department of Computer Science, [2]University of California, Irvine, Department of Computer Science, [3]Carnegie Mellon University, Robotics Institute, [4]American University, Department of Computer Science, [5]Cornell University, Department of Computer Science

When judging material properties of a translucent object, we often look at sharp geometric features such as edges. Image analysis shows edges of translucent objects exhibit distinctive light scattering profiles. Around the edges, there is often rapid change of material thickness, which provides valuable information for recovering material properties. Previous study found that perception of 3D mesoscopic shape is different between opaque and translucent objects. Here, we examine whether geometry affects perception of translucent material perception. The images used in the experiment are computer-generated using Mitsuba physically based renderer. The shape of an object is described as 2D height fields (in which each pixel contains the amount of extrusion from the object surface to the base plane). We varied both material properties and 3D shapes of the stimuli: for the former, we used materials with varying optical densities (used by the radiative transfer model) so that the object would have different levels of ground-truth translucency; for the latter, we applied different amounts of Gaussian blur to the underlying height fields. Seven observers finished a paired-comparison experiment where they viewed a pair of images that had different ground-truth translucency and blur levels. They were asked to judge which object appeared to be more translucent. We also included control conditions where the objects in both images have the same blur levels. We found that when there was no difference in the level of blurring between the images, observers could discriminate material properties of the two objects well (mean accuracy =81%). However, when the two objects differ in the blur level, all observers started to make more mistakes (mean accuracy = 71%). We conclude that observers' sensitivity to translucent appearance is affected by the sharpness of the 3D geometry of the object, thus suggesting 3D shape affects material perception for translucency.

26.324 **Visual Perception of Deformable Materials** Vivian C Paulun[1](Vivian.C.Paulun@psychol.uni-giessen.de), Filipp Schmidt[1], Roland W Fleming[1]; [1]Department of Psychology, University of Giessen, Germany

Visually estimating mechanical properties, such as stiffness or elasticity, is computationally challenging. A deformable object's shape and motion depends not only on its internal properties, but also on the external forces applied. Thus, to infer the object's properties, the visual system must somehow disentangle the causal contributions of multiple factors. To investigate how the brain achieves this, we simulated and rendered 20 short animations of rigid objects interacting with a non-rigid target object. We varied the type of interaction ('scene') as well as the target's stiffness and elasticity, i.e. whether the deformation was permanent (plastic) or the object returned to its original shape (elastic). Fifteen observers rated the apparent softness, elasticity and deformation of the targets. Despite large stimulus variations across scenes, responses were broadly in accordance with the simulated internal properties, although plastic objects were perceived softer than equally stiff elastic objects (presumably because plastic deformations were perceived larger than elastic deformations). Indeed, there was a strong correspondence between perceived stiffness and perceived deformation. We characterized the physical deformation of the objects by measuring seven deformation features (e.g. wobbling, stretching, curving) on the underlying 3D-meshes. Strikingly, we found that representing the stimuli in this 7-dimensional feature space systematically organized the stimuli by their internal properties, compensating for the effects of extrinsic factors. A linear combination of the features predicts softness perception very well (r = .93). Next, we simulated >100.000 animations in which we varied the scene layout, type and amount of external force, and the stiffness and elasticity of the target objects. This dataset allowed us to select stimuli with diverging predictions from different features to test the contribution of individual predictors and validate our model with new stimuli. The results suggest the brain achieves 'softness constancy' by representing deforming objects in a multidimensional feature space.

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26.325 **Distinguishing Mirror from Glass** Hideki Tamura[1,2](t-amura13@vpac.cs.tut.ac.jp), Konrad E Prokott[3], Roland W Fleming[3]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Japan Society for the Promotion of Science, [3]Department of Psychology, Justus-Liebig-University Giessen

Telling mirror from glass is highly challenging because both materials derive their appearance from their surroundings. Despite this, humans readily discriminate them, even when colour and luminance distributions are matched. To test how different visual cues contribute to this ability, we trained classifiers to discriminate renderings based on a range of features, and compared responses to human mirror/glass classifications on an image-by-image basis. We created over 750,000 renderings with either ideal mirror or ideal refractive materials, varying the shape, illumination and viewpoint. Then, three classifiers were defined by features based on simple pixel histograms ('Simple'), Portilla-Simoncelli texture statistics ('PS'), and three-layer convolutional neural networks ('CNN'). For randomly selected renderings, humans and all three classifiers performed well. Such high performance levels makes it hard to determine which cues the visual system uses, so to distinguish more precisely between classifiers, we selected a smaller subset of images for which the classifiers' responses were inconsistent, or consistently incorrect, forcing accuracy of the classifiers near to chance level. However, fifteen human observers judged those stimuli with 85% accuracy, suggesting humans use additional cues. The key challenge is to predict both successes and failures of human perception, so we then used Generative Adversarial Networks trained on renderings to create a new stimulus set that uniformly spanned the range from highly diagnostic to highly ambiguous. We then used Bayesian hyper-parameter search to identify CNN architectures that, when trained on standard renderings, also correlate highly with humans on these more ambiguous images. The resulting networks and images reveal many novel cues: e.g., mirrored surfaces tend to exhibit smooth, saturated colour gradients, while glass images have distinctive bright, low-saturation fringes. These insights allow us to create novel illusions.

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26.326 **Visual sensitivity to material differences** Matteo Toscani[1](Matteo.Toscani@psychol.uni-giessen.de), Dar'ya Guarnera[2], Giuseppe Claudio Guarnera[2], Jon Yngve Hardeberg[2], Karl R Gegenfurtner[1]; [1]Justus-Liebig-Universität Giessen, [2]Norwegian University of Science and Technology

The reflectance properties of a surface as a function of viewing and illumination directions can be described by the bidirectional reflectance distribution function (BRDF). Because of their high dimensionality and complexity, BRDFs are often approximated by analytical models with a small number of parameters. Our aim was to impose a perceptual metric on BRDF space by measuring discrimination thresholds, similar to the approach championed by MacAdam for color. We used the microfacet model by (Löw et al. 2012; ACM TOG), based on a modified ABC distribution (Church et al. 1989; Proc. SPIE), with 5 parameters controlling diffuse reflection, the index of refraction and the amplitude, width, and fall-off of the specular lobes. We measured discrimination thresholds in this five-dimensional space under two different natural illuminations. Separate thresholds were measured for each parameter, for increments and decrements around a single central point in the space of the parameters fitted to the MERL database. Six naïve observers were asked to detect which of four rendered blobby shapes was different in material. Adaptive staircases (QUEST) were run for each parameter and each illumination condition. We observed that observers could do the task for all 5 dimensions, i.e. all of the parameters lead to perceptually noticeable differences. Thresholds for all parameters, except the amplitude of the specular lobe, exhibited a strong degree of asymmetry between increments and decrements. Discrimination thresholds were relatively stable across different illuminations. Our results show that an approach determining visual sensitivity to small material differences is viable. Our goal is to combine the measurements of small differences to those of larger differences, as obtained by multi-dimensional scaling, to provide an overall metric of material appearance.

26.327 **ShapeToolbox: Creating 3D models for vision research** Toni P Saarela[1](toni.saarela@helsinki.fi); [1]Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki

Many studies on visual perception and cognition use physically realistic, rendered images of 3D computer graphics models as stimuli. Precise parametric control is often needed over variations in properties such as shape and surface corrugation. Such parametric control over stimulus properties is crucial in many experiments on material perception, object recognition, shape adaptation, and shape memory. It would thus be desirable to have a software tool that produces 3D shapes with the needed level of parametric control, is easy to use, can be extended and modified by the user if needed, and is free. We introduce the ShapeToolbox, a collection of tools for creating 3D models of various shapes. This toolbox is free, open-source software that runs on Matlab and Octave; on GNU/Linux, Mac OS, and Windows platforms. The toolbox provides a handful of "base shapes" (spheres, disks, planes, tori, surfaces-of-revolution, and so forth) that can then be perturbed and modified in various ways. The options for 3D shape perturbation include sinusoidal components, filtered noise, Gaussian bumps or dents, and user-provided custom functions, matrices, or images. All shape and perturbation parameters are given numerically (instead of, say, deforming the shape using a mouse). In addition to enabling precise control over the stimulus, this also makes reporting and replicating the stimuli and experiments easier. Different kinds of perturbation can be freely combined in a given model, and ShapeToolbox also supports the blending of two shapes. The main strength of the toolbox lies in its use from code, but simple graphical user interfaces are also included for 3D model design and blending. The models can be saved in Wavefront obj format for importing to rendering programs or OpenGL applications. To illustrate the use and usefulness of the toolbox, we report data from example psychophysical experiments on shape recognition and surface material discrimination.

Eye Movements: Faces, objects, scene recognition

Saturday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

26.328 **Perception of gaze direction using 3D virtual reality displays. Effect of Sclera and Head Orientation.** Diego Buitrago-Piza[1](dbuitra2@uwo.ca), Hitarth Dalal[2], Borna Mahmoudian[1], Rob Nicolson[4], Julio Martinez-Trujillo[1,2,3]; [1]Schulich School of Medicine and Dentistry, Western University, ON Canada, [2]Department of Physiology and Pharmacology, Robarts Research Institute, Western University, ON Canada, [3]Brain and Mind Institute, London ON, Canada, [4]Children's Health Research Institute, Lawson Health Research, London ON, Canada

Perceived gaze direction results from a mechanism that takes into account the orientation of the eyes and the head relative to the observer (Todorovic 2006). Studies using two-dimensional images have shown that head orientation influence perceived gaze direction (Wollaston illusion; see Langton 2000). However, this effect has not been studied using 3D images; it is possible that 3D cues modulate interactions between head and gaze direction. We clarify this issue by using 3D virtual reality displays of digitized faces while manipulating eye and head orientation. We also studied the effect of the white sclera on perceived gaze direction by replacing human eyes by macaque monkey eyes. We used an Oculus rift for stimulus presentation. The stimulus presentation and data collection were conducted using Unreal Engine 4. Within a virtual world, emotionally neutral human heads with human or monkey eyes with 3 head and 7 eye orientations were presented. Subjects (n=9) judged whether gaze pointed right or left relative to them. A Weibull function was fit to the data; α (point of equality) and β (slope) were determined for each subject. We found a head orientation bias corresponding to a repulsive effect only when using human-eyes (rightward head rotation; αMedian 2.89° vs 0.05°; signed-rank test; $p = 0.0039$; leftward head rotation; αMedian -2.74° vs 0.05°; signed-rank test; $p = 0.0195$). We also found that the slope of the psychometric curves was steeper using human-eyes (human-eyes vs monkey-eyes, βmedian 12.14 vs 3.87; signed-rank test; $p = 0.0053$). Subjects showed longer reaction times with monkey eyes (median difference= 61ms; Kruskal-Wallis $p< 0.001$). Our results showed that the Wollaston illusion is present in 3D displays, however, it vanishes when the white sclera is not present. This indicates that the white sclera in human eyes substantially contribute to improve the accuracy of gaze direction discrimination.

Acknowledgement: CIHR and NSERC

26.329 **Eye Movement Patterns in Face Recognition are Associated with Cognitive Decline in Older Adults: An HMM Approach** Cynthia Y.H. Chan[1](cyhcynthia@gmail.com), Antoni B. Chan[2], Tatia M.C. Lee[1,3], Janet H. Hsiao[1]; [1]Department of Psychology, The University of Hong Kong, [2]Department of Computer Science, City University of Hong Kong, [3]Laboratory of Neuropsychology, The University of Hong Kong

Current methods for early identification of neurodegenerative cognitive decline are typically based on neuroimaging technologies, which are expertise-demanding and not commonly available. Here we examined the potential use of eye tracking as an easily deployable and inexpensive

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screening tool through the Eye Movement analysis with Hidden Markov Models (EMHMM) approach. This approach summarizes a participant's eye movements in a visual task with person-specific regions of interest (ROIs) and transition probabilities among the ROIs in an HMM. Individual HMMs can be clustered to discover common patterns. Similarity between an individual pattern and a discovered common pattern can be quantitatively assessed using log-likelihood measures. This measure can be used to examine the relationship between eye movement patterns and cognitive performance. In experiment 1, we recruited young and older adults to perform a face recognition task and discovered "holistic" (mostly fixating around the face center) and "analytic" (frequent transitions among the two eyes and the face center) patterns. Significantly more older participants adopted the holistic pattern, whilst more young participants adopted the analytic pattern. The analytic pattern yielded better face recognition performance regardless of age. Importantly, older participants' cognitive status, as assessed by the Montreal Cognitive Assessment, was negatively correlated with eye movement similarity to the holistic pattern. Experiment 2 examined whether the holistic and analytic patterns discovered in Experiment 1 could be used to assess eye movements of new participants for screening purposes. New older participants performed the same face recognition task with different stimuli. Consistent with Experiment 1, high similarity to the holistic pattern was correlated with low cognitive status, particularly in executive and visual attention functioning. This result demonstrates well the power of the EMHMM approach, suggesting the possibility of using eye movements in a simple visual task as a fast, easily deployable, and inexpensive screening tool for cognitive decline.

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26.330 The development of processing face race and face sex in childhood.

Stefania Conte[1](s.conte6@campus.unimib.it), Ryan Barry-Anwar[2], Lisa Scott[2]; [1]Depatment of Psychology - University of Milano-Bicocca, [2]Department of Psychology - University of Florida

By the end of the first year, there is a shift from a female, own-race face processing advantage to a general own-race advantage (Tham et al., 2015). The present study sought to extend these findings and examine the development of processing race and sex later in childhood. Visual fixation patterns of 15 younger (3-4 years) and 8 older (5-6 years) Caucasian children were recorded. Children saw faces (2000ms) that varied by race (own/Caucasian, other/Asian), sex (female, male), and orientation (upright, inverted). Visual fixation similarity scores were calculated by examining temporal and spatial sequences of fixations (ScanMatch Toolbox, Cristino et al., 2010) and comparing them between participants within each age group. Children's fixation patterns were predicted to increase in similarity with age for faces within commonly experienced groups (i.e., female own-race faces). Younger children explored other-race faces more consistently than own-race faces ($p < .001$; Figure 1), whereas older children's similarity scores did not differ by race. However, the similarity scores for both own-race ($p < .001$) and other-race faces ($p < .05$) were greater for older than younger children. Interestingly, race did not interact with either inversion or sex. When viewing both upright male ($p = .001$) and female faces ($p < .05$) and inverted female faces ($p < .001$) older children used a more similar visual strategy than younger children (Figure 2). However, when viewing inverted male faces, younger and older children's strategies did not differ. Visual fixations patterns for both own- and other-race faces as well as female faces in both orientations are more similar for older than younger children. However, fixation patterns are more similar in older children for upright, but not inverted, male faces. These findings suggest that the developmental trajectories for processing face race and face sex differ in childhood.

26.331 Peripheral cues guiding the first eye movement to faces

Xiao(Nicole) Han[1](nicole7han@gmail.com), Puneeth N. Chakravarthula[1], Miguel P. Eckstein[1]; [1]Psychological and Brain Sciences, University of California Santa Barbara

Introduction: When identifying a face, a majority of humans direct their initial eye movements to a featureless point just below the eyes. Such preferred point of fixation maximizes face identification accuracy and is predicted by a theoretical model that takes into account the distribution of information across the facial features and the foveated nature of the visual system (foveated ideal observer, Peterson & Eckstein, 2012). However, the visual attributes of the face that are processed in the visual periphery and guide the destination of the first fixation into faces are not known. Here, we manipulated the position of facial features and the head frame to assess which attributes are utilized by the brain to guide the 1st eye movement. Methods: Observers identified a face (14 deg. height) presented for 1 sec. out of 4 possible faces. Their starting fixation was 5-7 deg. from the edge of the face. Across conditions, the configuration of the features within the face was manipulated (e.g., top to bottom: Mouth, Nose, Eyes; etc.), the head frame was eliminated, or a single feature was erased. Observers were free to make eye movements. Results: The endpoint of the initial fixation was not altered when the mouth or nose was erased but was directed to lower point along the face when the eyes were eliminated. Similarly, lowering the position of the eyes within the face also lowered the destination of the 1st saccade. Finally, eliminating the head frame also lowered 1st saccade locations along the face. Conclusion: The results suggest that the human brain relies heavily on the position of the eyes and the head frame to guide the first saccade into faces. Future research should investigate how the features guiding eye movements might interact with the initial position of the face in the visual periphery.

26.332 Stimulus and Cognitive Factors Influence the Spectatorship of Portraits

Tobiasz R Trawinski[1](tt1u14@soton.ac.uk), Natalie Mestry[2], Beth Harland[3], Nick Donnelly[1]; [1]School of Psychology, University of Southampton, United Kingdom, [2]Department of Psychology, Bournemouth University, United Kingdom, [3]Lancaster Institute for the Contemporary Arts, Lancaster, University, United

Portraits are a specific type of painting motif defined by the central focus of an individual or group (sitter(s)) in a painting. Studies of the spectatorship of portraits are often limited to considering the role of gaze in determining viewing (e.g. Tyler, 1998). Portraits are to be viewed in their totality, so we examine what other factors influence the spectatorship of portraits. We explored how sitter gaze influences spectatorship and how the presence of faces, bodies and other salient regions influence eye movements made during the viewing of portraits. These data are also considered with respect to individual differences in attention (Attention Network Test; Fan et al., 2002) and both verbal and spatial working memory (3-back task; Shackman et al., 2006). Participants with no specific art knowledge had their eye movements recorded whilst rating their liking of a set of 142 portraits on a 4-point Likert scale. The paintings were categorised as the primary sitter having focused or ambiguous gaze (using a separate rating study) and portraits as having salient regions in the context of the primary sitter or not (Itti & Koch, 2001). Regions of interest for the eye movement analysis were defined terms of faces, bodies or context. Results showed participants prioritised faces during the rating task, with increased number and duration of fixations compared with the bodies and context. Fixations became more concentrated on faces when gaze of the sitter was focussed and salient features were present in the background. The numbers of fixations made to the body were lower than to the face but higher than to the context. The tendency to fixate bodies was reduced in those with high spatial working memory capacity. The results are discussed in terms of a model that emphasises how stimulus and cognitive factors influence the spectatorship of portraits.

26.333 Causal influence of object representations on eye movements

Marek A. Pędziwiatr[1](pedziwiatrma@cardiff.ac.uk), Elisabeth von dem Hagen[1], Christoph Teufel[1]; [1]Cardiff University Brain Research Imaging Centre, School of Psychology, Cardiff University

Possible factors guiding eye-movements during the spontaneous exploration of natural scenes are currently a matter of a heated debate. Two main candidates have been put forward: low-level image features constituting bottom-up saliency and high-level object representations acting in a top-down manner. Saliency models are successful in predicting human eye-movements, a finding that has been argued to indicate oculomotor guidance by low-level features. Alternatively, these findings might result from the fact that low-level features and object locations are confounded in natural scenes. Another difficulty in resolving this debate is that the contributions of both factors might change over time: bottom-up guidance might prevail initially, with top-down factors taking over later.

Saturday PM

The current study contributes to this debate with a novel approach. We used ambiguous, two-tone images as stimuli. These are derived from photographs of natural scenes, the templates. On first viewing, two-tone images appear to consist of meaningless patches. Once an observer has acquired prior object-knowledge relevant to image content by viewing the templates, however, the visual system binds a two-tone image into a coherent percept of a scene. In Experiment 1, we collected eye-gaze data while observers free-viewed template photographs (Template condition) and when they saw two-tone images before (Unresolved) and after (Resolved) providing prior object-knowledge. In Experiment 2 we recorded first fixations after two experimentally controlled saccade-planning times in the same three conditions. Despite the fact that low-level features of two-tone images are identical in the Unresolved and Resolved conditions, observers' eye-gaze patterns in both experiments are more similar between Template and Resolved conditions than between Template and Unresolved conditions. The results shows that with task and stimulus properties kept constant, object representations override the influence of low-level features on oculomotor control already very early on. Therefore, acquiring object representations significantly alters where observers look when viewing natural scenes.

26.334 **Category-specific guidance of gaze in photographs and line drawings** Claudia Damiano[1](claudia.damiano@mail.utoronto.ca), John Wilder[1], Dirk B. Walther[1]; [1]Department of Psychology, University of Toronto

Our group has previously shown that scene content can be predicted from eye movements observers make when viewing colour photographs. The time course of category predictions reveals differential contributions of bottom-up and top-down processes at different viewing times. Here, we use these known differences in order to determine when and to what extent image features at different representational levels contribute toward guiding gaze in a content-specific manner. 77 participants viewed grayscale photographs and line drawings of real-world scenes. In a leave-one-subject-out cross validation analysis, scene categories were predicted from gaze patterns over a 2-second time course. Scene categories could be predicted from gaze at all times in both photographs (average accuracy = 31.4%, chance = 16.7%, $p < 0.0001$) and line drawings (30.0%, $p < 0.0001$). We also replicate the time course, with an initial steep decrease in prediction accuracy from 300ms to 500ms, representing the contribution of bottom-up information, followed by a steady increase, representing top-down knowledge of category-specific information. Using DeepGaze II as the leading model of salience, we reconfirm a strong early contribution of bottom-up effects in grayscale photographs. We computed the low-level (luminance contrasts and orientation statistics) and mid-level features (local symmetry and contour junctions) from the images in order assess their differential contributions to content-specific guidance of gaze. For photographs, we find qualitatively similar contributions of these representational levels, contributing mostly to the initial bottom-up peak. For line drawings of the same scenes, we observe that mid-level features that describe scene structure (symmetry and junctions) play a more prominent role in the top-down guidance of gaze. Thus, we show that bottom-up information contributes less to gaze behaviour for line drawings than for photographs, and that structural features increasingly guide category-specific gaze when images are reduced to line drawings.

26.335 **Semantic and Functional Relationships Among Objects Bias Gaze Control** Andrew Clement[1](aclemen3@nd.edu), Ryan E O'Donnell[2], James R Brockmole[1]; [1]University of Notre Dame, [2]Pennsylvania State University

A variety of factors are known to influence the control of gaze during scene viewing. For example, the semantic relationship between objects and the overall scene context is known to influence the allocation of gaze. Here, we assessed whether semantic and functional relationships between individual objects could bias gaze independently of a broader scene context. Participants began by fixating a central object (e.g., a key) flanked by two peripheral objects. After a brief delay, participants were free to shift their gaze to one of these objects. One of the peripheral objects could be semantically related (e.g., a lock) or unrelated (e.g., a bowl) to the central object, and the central object could be oriented to depict a functional or non-functional interaction with this object (e.g., a key pointing toward or away from a lock). When a functional interaction was depicted, participants were more likely to shift their gaze toward the semantically related object. However, when the central object was oriented away from this object, participants were equally likely to shift their gaze toward either of the two peripheral objects. Thus, the orientation of the currently fixated object strongly biased gaze, and could compete with the semantically related object for the control of gaze. In a second experiment, the central and peripheral objects were switched so that the orientation of the peripheral objects was manipulated. In this case, participants were more likely to shift their gaze toward the semantically related object, regardless of whether a functional or non-functional interaction was depicted. Thus, the orientation of the to-be-fixated objects did not bias gaze as strongly as the orientation of the currently fixated object. Collectively, these findings reveal that semantic and functional relationships among objects independently influence gaze control, and can bias gaze even in the absence of a broader scene context.

26.336 **Temporal priority of gaze during natural scene viewing** Kazuaki Akamatsu[1](kaz.akamatsu@uec.ac.jp), Yoichi Miyawaki[1,2]; [1]Graduate School of Informatics and Engineering, The University of Electro-Communications, [2]JST, PRESTO

The gaze is directed to various locations in the visual field from moment to moment for acquiring information necessary to recognize the external environment. Previous studies showed that the gaze is directed frequently to spatial locations with high saliency defined by lower-order visual features, suggesting that the visual system assigns the higher priority in spatial domain to fixate salient locations. However, it remains unclear whether gaze priority also exists in temporal domain and what characteristics of visual information dominates temporal gaze priority. To resolve this question, we recorded eye movements of human observers while they saw natural scene images and investigated visual information of gazed locations over time. Natural scene images were selected from large image databases (Mottaghi et al., 2014; Zhou et al., 2016) such that a number of presented object categories was as large as possible (> 100 categories). In this study, we particularly focused on difference in temporal priority of the gaze toward objects in the scene images and quantified the time course of gaze attraction for each object category after the onset of the image presentation. Results showed that the time course of gaze attraction varied with the object category. Hierarchical clustering revealed that there were at least two distinct clusters consisting of multiple object categories: a cluster attracting the gaze in the early period and the opposite one. These clusters appeared to disagree with conventional categories in superordinate levels. Control analyses further confirmed that variation in the time course of gaze attraction could not be explained by difference in saliency defined by lower-order visual features. These results suggest that the gaze is attracted fast to particular object categories and the temporal priority could be explained by higher-order visual features rather than lower-order visual features.

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26.337 **Oculomotor and Perceptual Adaptation to Natural Scenes Statistics** Agostino Gibaldi[1](agostino.gibaldi@berkeley.edu), Martin S Banks[1]; [1]School of Optometry, University of California at Berkeley

As we explore the 3D environment with our eyes, binocular coordination is required to allow both eyes to land on the object of interest quickly and accurately. From an analysis of natural-scene statistics, we know that points in the upper visual field are likely to be farther than the current fixation point, that points in the lower field are likely to be nearer, and that points to the left and right of fixation are likely to be farther. We investigated whether binocular eye movements are biased toward landing on the most likely depths in different parts of the visual field. We measured where the eyes land in depth when making upward, downward, leftward, and rightward saccades without visual feedback (aka open loop). The results show that open-loop movements are divergent with upward, leftward, and rightward saccades, and convergent with downward saccades. In other words, the initial landing points for binocular, open-loop saccades are consistent with the statistics of natural scenes. We also investigated whether this oculomotor behavior is compatible with the positions of corresponding retinal points in the two eyes. The externalization of those points is the horopter, which is the locus of points in space

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where stereo depth is most accurate. We asked whether the landing points for binocular, open-loop saccades tend to be on the horopter. We found that they are, which means that when the eyes move to a new position, the observed convergence or divergence is biased toward placing the landing point near the horopter such that that point stimulates corresponding points. Our results show that the oculomotor system is adapted to the statistics of natural scenes.

26.338 **Predictions Guide Gaze in Scene Search** Steven G Luke[1,2](steven_luke@byu.edu), Benjamin Jafek[3]; [1]Department of Psychology, Brigham Young University, [2]Neuroscience Center, Brigham Young University, [3]Department of Computer Science, Brigham Young University

Traditionally, models have focused on the role of visual salience in directing attention during real-world scene processing. However, recent research has suggested that meaningfulness plays a primary role, and specifically that eye gaze is guided by predictions (Henderson, 2016; Henderson & Hayes, 2017). We quantified predictability of search targets using a norming study in which participants were presented with scenes from the SCEGRAM image database (Öhlschläger & Võ, 2017). These scenes did not contain the search target, and participants indicated via mouse click where a given target would likely be located in the scene. Prediction maps were created from the data by applying a gaussian blur (sigma = 1 degree of visual angle). A separate group of participants then searched the scenes for these target objects while their eye movements were tracked. Fixation maps were produced from the eye-tracking data, specifically the location of the first fixation after the initial saccade from image center. Saliency maps werealso created for each image using graph-based visual saliency (Harel, Koch & Perona, 2006). Results indicate that the Prediction maps overlapped significantly with the Fixation maps when the target object was in or near the predicted location (r = 0.33). The Saliency and Fixation maps were more weakly related (r = 0.099). However, this Prediction map advantage disappeared when the target object was in an unusual location (e.g. the cereal bowl was on a chair instead of on the table; Prediction r = 0.095; Saliency r = 0.1). We also report the results of a deep neural network trained to use Predictability maps, saliency maps, and both together to predict eye fixation locations in an image. Together, these data indicate that prediction does guide gaze when peripheral visual information consistent with the prediction is available.

26.339 **Spatial working memory impedes search efficiency in interrupted but not continuous scene search** Mark Mills[1](mark.mills2@huskers.unl.edu), Matthew D Hilchey[1], Jay Pratt[1]; [1]Department of Psychology, University of Toronto

When searching through a scene, saccades tend to be slower to return to recently fixated locations (saccadic inhibition), whereas during scene memorization saccades tend to be faster to such locations (Dodd et al., 2009). Is the lack of evidence for inhibited saccades in tasks emphasizing scene memory a consequence of a goal-dependent mechanism or is the inhibition simply masked by other processes involved in scene memorization but not search? We provide evidence for the latter. Using an interrupted scene search task (Experiment 1) in which scenes abruptly expanded in size—which is considered to invoke memorial processes (cf. Thomas & Lleras, 2009)—we were able to eliminate saccadic inhibition. Moreover, applying a spatial working memory load prior to search further reduced search efficiency such that saccades were now faster to return to recently fixated locations. To test whether an additional memory process—brought online by scene interruption—obscured saccadic inhibition, Experiment 2 employed a continuous scene search task in which scenes remained continuously present throughout search. In this case, saccadic inhibition was observed, regardless of whether a spatial working memory load was applied or not. Thus, spatial working memory influenced interrupted but not continuous scene search. These data suggest that when confronting visual instability, processes related to working memory are brought online, obscuring saccadic inhibition and thus rendering search less efficient in the sense that rather than the eyes being propelled through the scene, the eyes are instead biased to return to an already fixated location.

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26.340 **Eye movement data of large-scale crowdsourced driving videos reveal distinct driver gaze patterns for different object categories** Ye Xia[1](yexia@berkeley.edu), Karl Zipser[2], Ken Nakayama[1,3], David Whitney[1,2,4]; [1]Department of Psychology, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley, [3]Department of Psychology, Harvard University, [4]Vision Science Group, University of California, Berkeley

Visual attention enables drivers to locate potential risks across the visual field within a small fraction of a second. Eye tracking is an effective way to approximate which areas human drivers are attending. However, studies of human drivers' eye movements are often limited by the size of the dataset. We collected human eye movement data for over 1,000 crowd-sourced driving videos. The subjects watched the driving videos in the lab while performing a "driving instructor task": they were asked to imagine they were driving instructors sitting in the copilot seat and they needed to press a button whenever they wanted to warn the student driver of any risk. Four to seven subjects watched each video. Spatiotemporal gaze distributions for different subjects were correlated with each other. We identified the most frequently foveated object categories and found that the gaze distribution within the objects themselves showed informative patterns. For example, subjects tended to look at the faces of pedestrians, and they tended to foveate the right rear end of cars merging from the left. That gaze patterns have particular "fingerprints" for different objects is consistent with the notion that particular regions of different objects can be more informative; for example, pedestrian faces provide useful information to drivers about his or her intended behavior. These gaze fingerprints were reliable. We were able to identify the category of an object based solely on the gaze distribution within the bounding box of that object. Moreover, we could distinguish between pedestrians entering into the roadway and exiting the roadway, and between cars merging from the left and merging from the right. These results suggest that human driver eye movement data contains rich information about the driving scene, information that could be harnessed in autonomous and assisted driving applications.

26.341 **Visuo-attentional strategies in road crossing situations across the lifespan** Victoria I Nicholls[1](vnicholls@bournemouth.ac.uk), Jan Wiener[1], Geraldine Jean-Charles[2], Peter de Lissa[2], Junpeng Lao[2], Roberto Caldara[2], Sebastien Miellet[1,2,3]; [1]Department of Psychology, Faculty of Science and Technology, Bournemouth University, [2]Department of Psychology, Faculty of Humanities, University of Fribourg, [3]School of Psychology, Faculty of Social Sciences, University of Wollongong

270,000 pedestrians die of road traffic accidents and millions are injured each year. Children and older adults are overrepresented in these groups. However, little is known about the perceptual processes used by vulnerable pedestrians. To investigate perceptual processes involved in road-crossing, we monitored visual exploration and road-crossing decisions in children from 5 to 15 years-old, adults aged 18-25, and older adults aged 60 or above while they watched road-traffic videos containing distractors (people) and a range of traffic densities. Data-driven clustering approaches found a critical age of under 10 at which children are more likely to cross the road in short gaps. Interestingly, decision biases under 10 were associated with visual biases. While the maximum gaze distributions were at the start of the vehicle's' trajectory for all age groups, gaze similarity matrices (GSMs) revealed more varied gaze patterns across trials for children under 10 than for adolescents, young and older adults. iMap4 (Lao et al., 2017) showed that the variability in gaze patterns for children under 10 can be explained by gaze towards distractors irrelevant to the road-crossing task (human beings) and towards approaching vehicles when the traffic density is high. For all age groups oculomotor characteristics are impacted by distractors and traffic density, suggesting attentional capture. We propose that adolescents, younger and older adults are able to inhibit gaze orientation towards irrelevant stimuli; thus maintaining their gaze to the optimal location for the task. In contrast, children under 10 are less able to inhibit orientation towards irrelevant stimuli thus reducing access to diagnostic information, impacting their decisions. Older adults showed similar general gaze patterns to younger adults except for specificities when using fine-grained temporal anal-

yses based on automatic image processing. Older adults' vulnerability is discussed in terms of delays in attention allocation, decisions, and decline in executive functioning.

26.342 **Discovery of activities via statistical clustering of fixation patterns** Jeffrey B Mulligan[1](jeffrey.b.mulligan@nasa.gov); [1]Human Systems Integration division, NASA Ames Research Center

Human behavior often consists of a series of distinct activities, each characterized by a unique pattern of interaction with the visual environment. This is true even in a restricted domain, such as a piloting an aircraft, where activities with distinct visual signatures might be things like communicating, navigating, and monitoring. We propose a novel analysis method for gaze-tracking data, to perform blind discovery of these hypothetical activities. The method is in some respects similar to recurrence analysis, but here we compare not individual fixations, but groups of fixations aggregated over a fixed time interval. The duration of this interval is a parameter that we will refer to as delta. We assume that the environment has been divided into a set of N different areas-of-interest (AOIs). For a given interval of time of duration delta, we compute the proportion of time spent fixating each AOI, resulting in an N-dimensional vector. These proportions can be converted to integer counts by multiplying by delta divided by the average fixation duration (another parameter that we fix at 280 milliseconds). We compare different intervals by computing the chi-square statistic. The p-value associated with the statistic is the likelihood of observing the data under the hypothesis that the data in the two intervals were generated by a single process with a single set of probabilities governing the fixation of each AOI. The method has been applied to approximately 100 hours of eye movement data collected from pilots in a high-fidelity B747 flight simulator, and the results have been compared to synthetic data in which the each activity is represented as first-order Markov process with random probabilities assigned to the AOIs. Randomly-generated synthetic activities can require thousands of fixations to be discriminated with statistical significance, while the human data can be clustered using averaging windows of some 10's of seconds, suggesting that the actual activities are much more narrowly focused than random Markov models.

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26.343 **Watchers Do Not Follow the Eye Movements of Walker** Michael Papinutto[1,2](michael.papinutto@unifr.ch), Denis Lalanne[2], Roberto Caldara[1]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg, Switzerland, [2]Human Centered Interaction Science and Technology (Human-IST) Institute, Department of Informatics, University of Fribourg, Switzerland

Where, when and how eye movements are performed to process the visual environment has been a question of great interest for scientists from a long time. Nowadays, eye-tracking technologies have become precise and affordable, generating an increasing amount of research studies. Even if the use of real-world videos in eye-tracking experiments was recommended from a decade (Henderson, 2003), most of the eye-tracking studies in the literature keep using impoverished representations of the visual environment in laboratory experiments. This experimental choice subtends the idea that eye movements obtained in the laboratory are comparable and representative of the ecological visual strategies deployed in the natural environment. Only a few studies have investigated eye-movements differences between laboratory and real-world conditions. However, these studies compared eye movements from the same observers confronted with different settings and tasks. Consequently, it remains unclear whether eye-movements deployed by active walkers freely navigating in the environment are similar to those of observers visualizing the same environment, when both are performing the same task. To tackle this issue, we asked participants to walk and actively look at the environment while wearing eye-tracking glasses (the Walkers). In addition, we tracked the eye movements of another group of observers (the Watchers), while they were actively exploring in the laboratory the videos (with sound) recorded from the Walkers. Walkers and watchers exhibited different fixation and saccade patterns, but similar fixation durations. Moreover, the Watchers exhibited greater sensitivity to visual saliency and motion than the Walkers, except when persons, actionable or readable objects were present in the scenery. Altogether, our data show that results obtained in laboratory do not entirely generalize to real-world vision, at least for ecological spatial navigation. Eye-movements findings obtained in laboratory studies should be interpreted with caution and, when possible, reproduced in ecological settings for validation.

Spatial Vision: Neural mechanisms

Saturday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

26.344 **Spatially specific delay period activity in the human superior colliculus.** Kevin DeSimone[1,2](desimone@nyu.edu), Kartik K Sreenivasan[2], Clayton E Curtis[1,3]; [1]Department of Psychology, New York Uninversity, [2]Division of Science and Mathematic, New York University Abu Dhabi, [3]Center for Neural Science

The superior colliculus (SC) is a key node in a distributed oculomotor network and mediates orienting behaviors such as saccadic eye-movements and gaze shifts. The SC is a laminar structure sitting atop the brainstem and contains two tightly registered retinotopic maps: a visual map in the superficial layer, and a motor map in the intermediate and deep layers representing the angle and amplitude of saccades (Wurtz & Albano, 1980; Sparks, 1986). However, this classical view of the response properties of the SC has been challenged by pharmacological inactivation of the deep layers of the SC in the macaque (McPeek & Keller, 2004; Lovejoy & Krauzlis, 2010). We sought to examine the extent to which the human SC is able to maintain representations of behavioral goals beyond simpler visual and/or motor responses. We hypothesized that the SC acts as a topographic map of spatial priority (Fecteau & Munoz, 2006), and predicted that we should find spatially specific representations of behavioral goals in human SC during a delay period between visual stimulation and motor execution. To test this, we used fMRI to measure SC activity while participants performed memory-guided saccades. We used an inverted encoding model (Sprague & Serences, 2013) to characterize the spatial tuning of SC activity during the task. First, we found robust and spatially specific univariate persistent activity during the delay period following presentation of the visual cue but prior to execution of the saccade. Second, we found that the multivariate delay period activity in the SC was tuned for the location of the memory-guided saccade but not the location of the visual cue or visually-guided saccade. These findings suggest that the human SC maintains a representation of task-relevant behavior and thus plays a role in cognition.

26.345 **Contrast gain control and functional architecture in macaque V1** Jenna G Kelly[1](jgk267@nyu.edu), Christopher Shooner[1], Luke E Hallum[1], J Anthony Movshon[1], Michael J Hawken[1]; [1]Center for Neural Science, New York University

Contrast gain control allows visual neurons to adjust their responsivity based on the total contrast of the visual input. We have recently shown in monkeys that the strength of gain control in primary visual cortex varies widely. We also observed that nearby neurons (recorded on the same electrode track) often showed similar gain control strength, suggesting a functional architecture. To further explore the nature of this architecture we measured gain control in V1 of 8 anesthetized macaques. We used 32-channel linear arrays to record multiunit responses at regularly spaced sites along penetrations at different angles to the cortical surface, ranging from nearly surface-normal to nearly tangential. Our stimuli were pairs of orthogonal sinusoidal gratings presented individually or superimposed as a plaid. We compared responses to each plaid with the sum of responses to its two components; the ratio of the measured plaid response to the sum of the component responses was used to quantify the strength of contrast gain control. For every electrode pair on the same track, we computed the similarity in gain control strength (using the fractional difference between ratios) and analyzed how similarity depended on physical separation. Regardless of approach angle, we found that similarity was highest at neighboring recording sites and decreased with distance between sites. We compared the distance-dependence of gain control to that of orientation tuning. As expected, nearby sites preferred similar orientations, but only for distances of 300 µm or less when averaged over approach angle. Similarity in gain control fell more gradually with distance: sites separated by as much as 500 µm were more similar than those farther apart. We found no correlation between orientation similarity and gain control similarity at any distance, suggesting independent architectures for these functional properties.

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26.346 **Characterizing Non-Linear Processes in Cross-Orientation Suppression (XOS) with Steady-State Visual Evoked Potentials (SSVEPs)**

Bruno Richard[1](bruno.richard@rutgers.edu), Ravi Sojitra[1], Bruce C Hansen[2], Patrick Shafto[1]; [1]1Department of Mathematics and Computer Science, Rutgers University, [2]Department of Psychology and Neuroscience, Colgate University

Normalization models of orientation masking define the percept of the target stimulus as the linear sum of the target and mask followed by rectification (i.e., a non-linearity). However, recent evidence (e.g., Baker & Wade, Cereb. Cortex, 27, 254-264) has suggested that stimulus combination in the early visual system is non-linear: target and mask signals undergo rectification prior to combination. Here, we aim to define the characteristics of target and mask combination (linear vs non-linear) when they have the same or different orientation (i.e., cross-orientation suppression). We used Steady-State Visual Evoked Potentials (SSVEPs) to record neural responses at flicker frequencies of the target (f1) and mask (f2), in addition to the characteristic signatures of non-linear response components (i.e., inter-modulation terms: f1+f2 and f2-f1). Target stimuli were 2° horizontal sinusoidal gratings with spatial frequency of 4 cycles/°, flickering at 5Hz, and generated at 5 different contrast levels (14, 20, 26, 32 and 36dB). Masks were identical to the target in size and spatial frequency, but flickered at 7.5Hz, were generated at a fixed contrast of 32dB, and offset in orientation to the target by 0° to 90° in steps of 15°. Response amplitude at f1 showed evidence of masking: amplitude increased monotonically with contrast and was rightward shifted compared to baseline for all but the co-oriented mask. Intermodulation term amplitude increased with target contrast when the target and mask were co-oriented or offset by 15°, but reduced to noise levels at larger mask orientation offsets. We implemented 5 model variants that define stimulus combination from fully linear to fully non-linear, and verify which is most apt at generating predictions that match our SSVEP data. We find our effects to be best explained by a fully non-linear model, and implement a geometric analysis to define the response surface of non-linearities measured with SSVEPs.

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26.347 **Enhanced Alpha-mediated inhibition on target when it is crowded by flankers**

Qiming Han[1,2,3,4](qmhhhan@pku.edu.cn), Jianrong Jia[1,2,3,4], Huan Luo[1,2,3]; [1]School of Psychological and Cognitive Sciences, Peking University, Beijing, China, [2]IDG/McGovern Institute for Brain Research, Peking University, Beijing, China, [3]Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China, [4]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China

Crowding is known as a perceptual phenomenon where the identification of objects presented far away from the fovea is impaired by the presence of neighboring flankers. Previous psychophysical and brain imaging studies have suggested that the crowding effect reflects top-down influence (e.g., insufficiency of attention resolution at the target) or a bottom-up process (e.g., originating from early visual processing). To examine the associated spatiotemporal neural processing underlying crowding effect, a key challenge is to dissociate the brain response for the target and flankers and monitor their respective neural activations as well as their interactions. In the present EEG study, subjects were asked to discriminate the orientation of a grating target presented on the peripheral visual field. The grating target was presented with grating flankers, and the intensity of crowding effect was manipulated by adjusting the orientation difference between the target and flanker gratings ("high-crowding" and "low-crowding"). Next, we employed a temporal response function (TRF) approach to dissociate the neuronal response that specifically tracks the target and flankers from the same EEG signals. Eye movement was monitored to ensure that subject fixated at the central fixation point. Preliminary data (N=6) demonstrates significant difference in crowding effect in behavioral performance between the high- and the low-crowding conditions. Furthermore, target for the high-crowding condition showed stronger alpha-band (~ 10 Hz) response in the latency of 300-400 ms than that for low-crowding condition, indicating an enhanced inhibition on the target. In sum, the observed association between the crowding effect and the late inhibitory alpha-band oscillation supports the view that crowding effect is attributed to attention-related top-down modulations.

26.348 **Stimulus dependence of population receptive fields within the visual field maps and the visual word form area**

Rosemary K Le[1](rosemary.le@stanford.edu), Chen Gafni[2], Michal Ben-Shachar[2], Brian Wandell[1]; [1]Psychology Department, Stanford University, [2]Gonda Brain Research Center, Bar-Ilan University

Background FMRI responses to text in the visual word form area (VWFA) are larger than responses to other stimulus types. Here we try to understand the origin of these differences by analyzing signals in the visual field maps (V1, V2, V3, hV4). While the magnitude of the fMRI signal may not differentiate words vs. nonwords in the visual field maps, models of the signal may differentiate these stimulus types. Specifically, population receptive field (pRF) measurements for words versus nonword stimuli may differ not only in the VWFA but also in the visual field maps. Methods We fit pRFs to three types of stimuli: words, false font, and checkerboards. The subject performed a task at fixation while a rectangular aperture containing the stimulus traversed the visual field. Other stimulus manipulations included word size, language (Hebrew vs. English), and aperture size. We compared pRF estimates for different stimulus types across the visual areas and in the VWFA. Results Compared to word stimuli, pRFs measured with false font stimuli only differ in the VWFA. Compared to word stimuli, pRFs measured with checkerboard stimuli differ in the visual field maps. This difference is small in V1 and increases along the visual hierarchy. Compared to English words, pRFs measured with Hebrew words differ in the VWFA and and slightly in V3v, but not in the earliest visual field maps (V1 or V2v). Aperture size and word size also affect pRF parameters. Conclusions Language and stimulus properties have effects not only within the VWFA but also in the visual field maps. PRF modeling captures differences not observed in the magnitude of the fMRI signal. These differences may be relevant to modeling proper word form recognition and reading ability.

26.349 **Effects of Transcranial Electric Stimulation to Early Visual Areas on Regional BOLD fMRI Activity During Visual Task**

Keishi Nomura[1](nomura@fechner.c.u-tokyo.ac.jp), Shuhei Shima[1], Kristina M Visscher[2], Aaron Seitz[3], Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo, [2]Department of Neurobiology, University of Alabama at Birmingham, [3]Department of Psychology, University of Calfornia Riverside

Transcranial electric stimulation (tES) has attracted considerable interest due to its potential to improve our understanding of the relationship between brain activity and human behavior. While there is a vast amount of literature on the behavioral effects of tES, less is known about its effects on visual perception and how the underlying neural modulation is spatially and temporally organized at local neural circuit level. Here we applied tES to human early visual areas during a visual task, aiming to examine its effects on regional blood oxygen level-dependent (BOLD) activity and to compare the effects of different tES techniques. Twelve subjects participated in five fMRI sessions on five different days, during which different types of stimulation were delivered: transcranial direct current stimulation (tDCS), 10 Hz transcranial alternating current stimulation (tACS), high-frequency transcranial random noise stimulation (hf-tRNS), low-frequency transcranial random noise stimulation (lf-tRNS), and sham. We used the following electrode montage: anode over the Oz and cathode over the Cz. In each session, the subject underwent three 12-minute scans during an orientation discrimination task. tES was applied only during the second scan. Changes in the regional BOLD activity during stimulation (online effects) were defined as the contrast between task-driven activity during the second and first scans, and changes in the BOLD activity after stimulation (after-effects) were defined as the contrast between the third and first scans. 10 Hz tACS induced an increase in BOLD activity evoked by the task in the right inferior and middle temporal cortex, which are distant from the stimulation sites. No after-effect was observed. Other stimulation methods failed to show significant online or after effects detectable at a group level. These results support the idea that the effects of tACS at alpha frequency are not limited in stimulation sites and rather spread to large-scale visual networks.

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Saturday PM

26.350 **Measuring cortical temporal contrast sensitivity across population receptive field (pRF) eccentricity and sizes using fMRI**

Marc M Himmelberg[1](marchimmelberg@gmail.com), Alex R Wade[1]; [1]Department of Psychology, University of York

The visual system's sensitivity to contrast and temporal frequency (TF) changes across visual space due to differences in retinal cell sensitivity. First, peripheral photoreceptors respond faster, and are therefore more sensitive to rapidly changing input, compared to more foveal photoreceptors. Second, there is an eccentricity-dependent decrease in the ratio of midget:parasol retinal ganglion cells (RGCs), leading to increased sensitivity to TF and contrast in the peripheral visual field. Are these retinal sensitivities maintained within the visual cortex? Here, we use functional magnetic resonance imaging (fMRI) to measure contrast response functions (CRFs) at four TFs, comparing responses at different population receptive field (pRF) eccentricities and sizes in V1, V2, V3, V3a and V4. Nineteen participants completed an event-related fMRI experiment that measured sensitivity to a contrast-reversing sine grating at 20 combinations of TF (1, 5, 10 20Hz) and contrast (1, 4, 8, 16, 64%). pRF maps were collected for each participant to provide eccentricity and pRF size estimates. Within retinotopically defined regions, we partitioned our data into foveal (0.20° - 3°), parafoveal (3° - 6°), and peripheral (6° - 10°) eccentricities, and small and large pRF sizes. We fit responses with hyperbolic ratio functions at each TF to generate CRFs, extracting C50 (contrast sensitivity) and Rmax (maximum response) parameters. In V1-V3a, C50 measurements indicated increased contrast sensitivity at high TF (20Hz) in peripherally tuned voxels. Increased contrast sensitivity was found in larger pRFs in all visual areas. Overall, visual areas were most sensitive to 10Hz flicker, in line with previous literature. Finally, Rmax increased in larger pRFs, independent of TF, in V1 and V2. Our data reflect a cortical representation of the retinal mechanisms that facilitate increased sensitivity to TF and contrast in peripheral vision. These findings may suggest the functional organisation of the visual cortex originates in the organisation of retina.

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26.351 **Efficient Mapping of Spatial Frequency Sensitivity in Human Visual Cortex**

Sara Aghajari[1](aghajari@bu.edu), Sam Ling[1]; [1]Boston University

Neurons within early visual cortex are selective for basic image statistics, including the spatial frequency content of a retinal image. However, sensitivity is not uniform across all frequencies, peaking at mid-frequencies, and dropping off for both low and high frequencies. How does the window of spatial frequency sensitivity vary across the visual field and across visual areas? Although a handful of previous studies have investigated this using conventional fMRI designs and analysis methods, these measurements are time-consuming and often do not span the entire range of spatial frequencies. In this study, we introduce a model-based fMRI analysis approach that allows for fast and efficient estimation of population spatial frequency tuning (pSFT) for independent voxels. BOLD responses within early visual cortex were acquired while subjects viewed a series of full-field stimuli that swept through a large range of spatial frequency content. Each stimulus was generated by bandpass filtering white noise with a central frequency that changed periodically between a minimum of 0.5 cpd and a maximum of 12 cpd. To estimate the underlying frequency tuning of each voxel, we assumed a Gaussian pSFT and optimized the parameters of this function by fitting our model output with the measured BOLD time series. With these estimated parameters, we can investigate the relationship between spatial frequency selectivity and other factors, including retinotopic preference and receptive field size.

26.352 **Mapping Spatial Frequency Preferences in the Human Visual Cortex**

William F Broderick[1](billbrod@gmail.com), Noah C Benson[2], Eero P Simoncelli[1,3], Jonathan Winawer[2]; [1]Center for Neural Science, New York University, [2]Dept. of Psychology, New York University, [3]Howard Hughes Medical Institute

Neurons in primate visual cortex are tuned for spatial frequency, and this tuning depends on eccentricity. Several studies have examined this dependency using fMRI (Henriksson et al. 2008; Sasaki et al. 2001; D'Souza et al. 2016), but they report preferred spatial frequencies (tuning curve peaks) at a given eccentricity in V1 that differ by one to two octaves, perhaps due to differences in stimuli or analysis methodology. Here, we systematically map this dependency using a population receptive field analysis of fMRI responses to a novel set of stimuli. The stimuli are constructed as mixtures of circular and radial gratings (pure circular, pure radial, or spirals). For any local region of the visual field, these stimuli cover a broad range of spatial frequencies and orientations, and the local spatial frequency of all stimuli varies inversely with eccentricity. We then used an unsupervised denoising algorithm (GLMdenoise; Kay et al. 2013) to estimate the response amplitude of each voxel to each stimulus, and combine these data with subjects' retinotopic maps (Benson et al. 2014; Dumoulin and Wandell 2008) to determine the relationship between the eccentricity of a voxel's population receptive field and its spatial frequency tuning at several orientations. We show that over a range of eccentricities from two to eight degrees, the preferred spatial frequency varies as the inverse of the eccentricity. Given that population receptive fields grow approximately linearly with eccentricity, these results are broadly consistent with a simple scaling rule, whereby peak spatial frequency tuning is inversely proportional to both population receptive field size and to eccentricity.

26.353 **The Neural Correlate Of Size Constancy Measured With SSVEP In Virtual Reality**

Meaghan McManus[1,2](mcmanus1@yorku.ca), Jing Chen[2], Laurence R Harris[1], Karl R Gegenfurtner[2]; [1]York University, [2]Justus Liebig University Giessen

When standing in a hallway and a person walks away from you, the retinal image of the person decreases, however, you still perceive them as being the same size. This is referred to as size constancy. If the retinal size were to remain constant as they get further we would perceive the person as getting larger. Previous findings from fMRI suggest that the perceived size of an object correlates with activation in V1 (Murray et al, 2006; Sperandio, et al., 2012). We explored how much the steady state visually evoked potential (SSVEP) would be modulated by the perceived size of an object relative to its retinal size. Participants viewed an environment presented in virtual reality (Oculus Rift) that had either strong distance cues (a hallway with stereo view), or limited distance cues (a featureless environment with monocular viewing). During a given trial participants saw an alternating black and white square flashing at 5hz at either 40cm or 80cm. The size of the near object increased and then decreased between 1.4 and 5.6cm over the course of 40 seconds. The sizes used for the far object were matched to the retinal sizes of the near object. At a fixed simulated distance, the amplitude of the SSVEP showed a strong dependence on the retinal size. At the same retinal size, the SSVEP amplitude was larger for the far distance compared to the near stimuli in the hallway environment. We conclude that the SSVEP over occipital cortex, presumable driven mainly by activity in V1, reflects the activation of size constancy mechanisms. ACKNOWLEDGEMENTS This study is supported by DFG IRTG 1901 and a research studentship from the NSERC CREATE program to MM.

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Perceptual Learning: Perception and performance

Saturday, May 19, 2:45 - 6:45 pm, Banyan Breezeway

26.354 **REM sleep facilitates post-sleep visual perceptual learning (VPL) by eliminating anterograde interference from pre-sleep VPL**

Masako Tamaki[1](tamaki@brown.edu), Aaron V Berard[1], Takeo Watanabe[1], Yuka Sasaki[1]; [1]Brown University

The role of REM sleep in VPL has remained elusive. We have previously found that both REM sleep and wakefulness stabilize VPL: If two different types of visual training occur successively with no interval, the first VPL training is retrogradely interfered with by the second VPL (Seitz et al, 2005; Yotsumoto et al, 2009). However, if REM sleep or wakefulness occurs during the interval, no retrograde interference was observed, indicating that REM sleep and wakefulness allow VPL to stabilize. Does this indicate that REM sleep and wakefulness have the same role in VPL? To address this question, we examined whether both REM sleep and wakefulness between the first and second types of visual training eliminate anterograde interference (from first on second VPL) as well as retrograde interference (from first on second VPL). Two blocks of training on the texture discrimination task with orthogonal orientations of background

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lines (1st-TDT and 2nd-TDT) were separated by a 2-hr interval. During the interval, subjects either slept (sleep group, n=12) or stayed awake (wake group, n=9). Performance was measured before and after trainings for both 1st-TDT and 2nd-TDT. The results showed that no retrograde interference occurred in the subjects from the wake group and those who showed REM sleep from the sleep group (REM-present), consistent with our previous findings. However, anterograde interference was observed for the wake group, but not for the REM-present group. Moreover, the amount of VPL of the 2nd-TDT was significantly correlated with the REM-sleep duration. These results suggest that REM sleep facilitates new VPL after sleep by eliminating anterograde interference from pre-sleep VPL. It has been reported that REM sleep prunes newly formed but unnecessary dendritic spines, which leaves room for the formation of even newer spines. This spine dynamics during REM sleep could account for the current results.

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26.355 **Evaluating the performance of the staircase and quick Change Detection methods in measuring perceptual learning** Zhong-Lin Lu[1](lu.535@osu.edu), Pan Zhang[1], Yukai Zhao[1], Barbara A Dosher[2]; [1]Department of Psychology, The Ohio State Unversity, [2]Department of Cognitive Sciences, University of California, Irvine

The staircase method has been widely used in measuring perceptual learning. Recently, Zhao et al (2017) developed the quick CD method and applied it to measure the trial-by-trial time course of learning. Here, we evaluate the performance of the staircase and quick CD methods. An observer with an exponential learning curve (time constant = 50 trials) in a 2AFC task was simulated. A 3-up/1 down staircase with six step sizes (1%, 5%, 10%, 20%, 30%, and 60% increase or decrease of contrast) and the quick CD were used to estimate the contrast threshold of the simulated observer, each starting from five different contrasts (+50%, +25%, 0, -25%, and -50% from the true threshold), with 400 trials in each of 1000 simulated runs. Thresholds were estimated every 80 trials. We found that: (1) The average absolute bias (AAB) of the trial-by-trial threshold estimates from quick CD was 0.016, with an average standard deviation (SD) of 0.039, all in log units. (2) Threshold estimates from the entire learning curve using quick CD were nearly unbiased (only 0.007), with an average SD of 0.026. (3) Staircases with 1% and 5% step sizes sometimes failed to generate more than seven reversals and could not be used to estimate the threshold in 80 trials. (4) The AAB and SD of the estimated thresholds were 0.053/0.047/0.048/0.080 and 0.046/0.053/0.061/0.087 for staircases with step sizes of 10%, 20%, 30%, and 60%, respectively. (6) The bias after the first block were 0.049 for quick CD, and 0.182/0.153/0.133/0.164 for staircases with the five different step sizes. All these results varied very little with the starting contrast. We conclude that the quick CD method provides more accurate and precise measures of perceptual learning than the staircase method. The optimal step size of the staircase is about 10%.

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26.356 **Spatial selectivity of tilt aftereffect depends on long-term history** Ron Dekel[1](ron.dekel@weizmann.ac.il), Dov Sagi[1]; [1]Department of Neurobiology, Weizmann Institute of Science

The tilt aftereffect (TAE) is taken to reflect short-term experience effects on perception, on the scale of seconds to minutes, but the rules governing the temporal integration of the underlying causes are not clear. TAE is explained by local effects attributed to accumulated sensory adaptation, but higher-level effects depending on statistical regularities in the adapting sequence are also implicated (Pinchuk-Yacobi, Dekel, & Sagi, 2016). Here we attempt to isolate short-term and long-term effects in the generation of TAE. We used a massed repetition design (Adaptor-Test trials: "AT", adaptors oriented ±20°, randomly mixed, N=6 observers) to measure the magnitude and spatial selectivity of TAE for briefly presented peripheral Gabor patches (Adaptor and Test duration=50ms, ISI=600ms, λ=0.3°, σ=0.6°, contrast=50%, eccentricity=2.1°). Results showed standard retinotopic TAE ("ipsi": 1.2±0.55°, Mean±SD), non-local TAE (when adaptation and test at opposite sides of fixation, "contra": 0.6±0.5°), and a surprising correlation between ipsi and contra (R2=0.78, p=.02) permitting a stable description of TAE in terms of its spatial selectivity (ipsi-contra, M=0.6±0.25°, Mean±SD). Next, we used a sterilized repetition design ("V--AT", N=4 observers), where a vertical Gabor presentation ("V") and a pause ("--", duration=1200ms) precedes each AT event. This design showed a larger local TAE (1.7±0.7°, Mean±SD), but a somewhat reduced contra TAE (0.3±0.4°), showing a stronger spatial selectivity (ipsi-contra: 1.4±0.46°, Mean±SD, p=0.03). Importantly, AT and V--AT measured identical TAE when mixed in blocks ("V--AT/AT/AAAAT" design, N=4 observers), equating long-term history. Thus the measured AT vs V--AT differences are due to a mechanism operating on slow timescale, possibly reflecting long-term statistics. We conclude that TAE has a short-term local component, probably sensory, and a longer term component reflecting stimulus statistics over longer time.

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26.357 **Idiosyncratic directional preferences in ambiguous perception are not modified to reduce ambiguity** Alexander C Schütz[1](alexander.schuetz@staff.uni-marburg.de), Byung-Woo Hwang[1]; [1]Experimental and Biological Psychology, Philipps-University Marburg

Idiosyncratic directional preferences have been reported in several exemplars of ambiguous perception, such as perceived depth order in transparent motion (Mamassian & Wallace, 2010), perceived tilt in structure-from-motion (Wexler et al., 2015) or perceived motion direction in apparent motion (Schütz, 2014). Although these preferences are widespread across individuals and stimuli, their functional relevance remains elusive. Here we tested the hypothesis that the function of these biases is to minimize ambiguity and perceptual decision costs. In this case, presenting stimuli more frequently along the most ambiguous axis should alter the directional preference to reduce ambiguity along this axis. In two separate experiments, observers had to report the perceived motion direction in an apparent motion stimulus that was consistent with two opposite motion directions or the motion direction they perceived in front in a transparent motion stimulus. In a pre-phase, all stimulus axes (0° to 170° in 10° steps) were equally likely and we measured observers' individual directional preferences. In a test-phase, either the least ambiguous axis, parallel to the individual preference, or the most ambiguous axis, orthogonal to the individual preference was shown in 40% of trials. In the remaining trials, all other axes were equally likely to measure individual preferences. A post-phase was identical to the pre-phase to detect potential aftereffects. Replicating previous findings, our results showed pronounced directional biases in both experiments. Individual preferences changed slightly between pre-, test and post-phases, but the amount of change was not modulated by the axis that was presented more frequently, parallel or orthogonal. Altogether, our results indicate that the reduction of ambiguity is not the primary aim of directional preferences. Since directional preferences can be adapted according to their usefulness for an additional task (Chopin & Mamassian, 2011), this suggests that perceptual ambiguity is not avoided by the visual system.

26.358 **Contingent adaptation in masking and surround suppression** Hörmet Yiltiz[1](hormet.yiltiz@nyu.edu), David J. Heeger[1,2], Michael S. Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Background: Adaptation describes changes in neuronal gain in response to recent input history. The classic gain-control model of adaptation predicts that a neuron's output depends only on its own recent input. A new model, the Hebbian normalization model (Westrick, Heeger and Landy, 2016), suggests that the normalization weight, whereby one neuron inhibits another, is correlated with the recent history of the product of their responses. This suggests a behavioral correlate: If two stimuli co-occur during adaptation ("contingent adaptation"), each stimulus should be more effective at suppressing the other. We test this prediction in two experiments. Method: Experiment 1 (overlap masking): observers adapted to two co-located high-contrast gratings (e.g., ±15 deg orientation) presented either (1) simultaneously (a plaid) alternated in time with a blank (±15 plaid, blank, ±15 plaid, blank, …; contingent adaptation) or (2) alternating in time (+15, -15, +15, -15, …; asynchronous). After adaptation, observers performed a contrast-detection task for one of the gratings at low contrast masked by a co-located, high-contrast grating at the other orientation (spatial 2IFC). Experiment 2 (perceived contrast): Adapters were a pair of gratings (a center disk and surrounding ring) alternating between the two orientations. In one location, center and

surround had the same orientations (+15/+15 alternated with -15/-15); in the other location, they had the opposite contingency (+15/-15 alternated with -15/+15). After adaptation, observers were shown high-contrast surround gratings with intermediate contrast center gratings, and chose the side with higher center contrast (spatial 2IFC). Results: Experiment 1: Contingent adaptation raised detection threshold compared to asynchronous adaptation. Experiment 2: Perceived contrast of the center grating was reduced when the pair of center/surround orientations matched the contingency in that location present during adaptation. Conclusions: Our results support the Hebbian normalization model of adaptation.

26.359 **Learning Complex Texture Discrimination** Jessica C Herrington[1](jessica.herrington@anu.edu.au), Ted Maddess[1], Dominique Coy[1], Corinne F Carle[1], Faran Sabeti[1], Marconi Barbosa[1]; [1]Eccles Institute for Neuroscience, John Curtin School of Medical Research, Australian National University

Different isotrigon texture types are only discriminable from random binary patterns and each other by their third and higher-order spatial correlations. Their mean contrast and spatial frequency content is identical to random noise. Our ability to make these discriminations has be proposed to be innate. We previously investigated learning of 17 isotrigon types in seven naïve subjects, where each type was tested in 14 sessions over 6 weeks. Significant learning was observed. Here we examined if 7 learning sessions conducted every 30 minutes on one day achieved similar learning. We also tested participants at a recall session, 2.5 months later. We used 11 naïve subjects with normal vision. We examined discrimination from random patterns of a subset of 5 of the original texture types, with 16 4AFC repeats/texture/session (5*11*8*16=7040 discriminations). Learning was similar to that achieved in the 6-week sessions. Two of the textures showed significant learning with mean discrimination improvement in probability of correct discrimination of 0.125 ± 0.058 to 0.244 ± 0.089 (p = 0.03 and 0.01). The textures that showed significant learning were the Cross-Even and Wolf-Odd type. However, both of these textures showed a reduction in learning at the final recall session. It appears that the number of discriminations, rather than the duration of the learning period is the key factor in learning differences in texture appearance based upon higher order spatial correlations. Initial performance was not chance so there appears to be some innate ability in naïve subjects.

26.360 **Task irrelevant statistical regularities modulate perceptual learning in orientation discrimination task** Jozsef Fiser[1](fiserj@ceu.edu), Gabor Lengyel[1]; [1]Department of Cognitive Science, Central European University

Perceptual learning is defined as the ability to improve one's performance in basic discrimination tasks via extended practice. Is this process influenced by statistical regularities in the scene that have no relation to the discrimination task at hand? Using a 5-day standard perceptual training protocol, we trained two groups of observers to perform an orientation discrimination task with Gabor patches. For one group, the background color of the scene changed across trials according to a fixed sequence, while for the other group, the background color changed randomly throughout the training. Baseline and post training discrimination thresholds were assessed in three conditions: (1) with randomly changing background colors, (2) with backgrounds following the fixed color sequence, and (3) with gray background. Overall, the group trained with fixed color sequence learnt more (had a larger reduction in orientation threshold by the end of the fifth day) than the group trained with randomly changing colors. Furthermore, while there was no difference across the baseline thresholds in the three conditions before training, after training, observers in the fixed sequence group showed the lowest threshold with fixed color sequence of the background, while their thresholds with random, and gray backgrounds were equally worse (higher). In contrast, observers in the random sequence group showed the lowest threshold during post test with the randomly changing background, intermediate thresholds with gray background, and the worst thresholds with fixed color sequence. Our results suggest that task irrelevant statistical structure in perceptual tasks is automatically and implicitly built in the developing internal representation during learning, and it can differentially affect the learning process. Moreover, altering such irrelevant context after learning has a highly specific effect on performance arguing for the emergence of a complex internal representation even in the simplest perceptual learning tasks.

26.361 **Higher Order Structure in Visual Statistical Learning** Anna Leshinskaya[1](alesh@sas.upenn.edu), Sharon L Thompson-Schill[1]; [1]University of Pennsylvania

An important aspect of perception is knowing the structure of our visual world, such as what objects or events are likely to co-occur. Experiments in visual statistical learning show that participants spontaneously and implicitly learn such predictive structure (e.g., Fiser, J., & Aslin, R. N. [2001]. Unsupervised statistical learning of higher-order spatial structures from visual scenes. Psychological Science, 12[6], 499–504.) Here we probed whether visual statistical learning can produce higher-order knowledge: predictive relations among predictive relations. Participants performed a cover task while watching sequences composed of eight distinct events. Sequences followed certain 'rules', where a rule specified which two of the eight events were predictive. Three sequence types were shown, cued by a distinct background object. The first two sequences each followed two rules (R1 & R2 and R3 & R4), where each rule held between a unique pair of events. A third sequence contained either a consistent pairing of rules (R1 & R2) or an inconsistent pairing (R1 & R3). Critically, consistency was defined not by which events appeared, but whether the same four events participated in rules (vs. appeared randomly). Although participants had minimal awareness of these rules, their performance on forced-choice tests indicated reliable learning. Importantly, performance on the third sequence was affected by pairing consistency. Participants who saw an inconsistent pairing performed worse on the third sequence relative to their baseline ($t[187] = 2.30$, $p = .023$), while participants who saw a consistent pairing showed no change, yielding a significant interaction ($F[1, 374] = 5.33$, $p = .022$). Thus, learners spontaneously and implicitly encoded how predictive relations themselves cohere into higher-order sets, affecting their learning of new evidence. The expectation that rules which cohered in the past will continue to cohere in the future may help us build generalizable structured models of our visual world.

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26.362 **Visual processing during false alarms indicates how short-term expectation shapes perception** Christoph Teufel[1](-teufelc@cardiff.ac.uk); [1]Cardiff University Brain Research Imaging Centre, School of Psychology, Cardiff University

Why do observers sometimes report seeing stimuli when none are presented? The nature of the processes underlying such false alarms has been a fundamental question ever since the early days of psychophysics. The objective of the current project was to better understand the role of short-term expectation in these reports. Conventionally, expectation is thought to affect false alarms by influencing strategic response rates. Recent work, however, highlights the role of expectation in shaping perceptual processing itself. It is thus possible that expectation shapes perceptual experience even in the absence of sensory input. To test this notion, I studied the processes underlying the influence of expectation on perceptual performance in general and, particularly, during false alarms. In a statistical learning paradigm, observers implicitly learned to expect a non-uniform distribution of orientations of Gabor patches. This expectation leads to predictable and systematic biases in orientation estimates in response to stimuli that are presented around psychophysical thresholds and that observers report having seen. Moreover, a similar pattern is seen for false alarms: even on trials when no stimulus was presented, orientation estimates accord with the distribution of expected orientations if observers report having seen a signal. In a set of experiments, I demonstrate that this pattern of estimates may be explained in part by a motor bias acquired during the initial learning of orientation distributions. However, a robust bias remains even when opportunities for motor learning are eliminated. Based on a neurophysiologically-plausible population code simulation, a range of possible models explaining this perceptual bias are compared. Overall, the empirical and computational results suggest that false alarms are not simply due to strategic responses. Rather, in the absence of sensory input, and having accounted for motor biases, the visual system internally generates a genuine percept through top-down influences of expectation.

26.363 Representing color and orientation ensembles: Perceptual learning of multiple feature distributions

Sabrina Hansmann-Roth[1], Andrey Chetverikov[2], Árni Kristjánsson[1]; [1]Icelandic Vision Lab, School of Health Sciences, University of Iceland, [2]Visual Computation Lab, Center for Cognitive Neuroimaging, Donders Institute for Brain, Cognition and Behavior

Objects have a variety of different features that can be represented as probability distributions. Previous findings show that besides mean and variance, the visual system also encodes the distribution shape, both for color and orientation ensembles (Chetverikov et al. 2016, Cognition; Chetverikov et al. 2017, Psych. Science). In an odd-one-out search task we investigated observers' ability to learn multiple feature distributions simultaneously. Our stimuli were defined by two distinct features (color and orientation) while only one was relevant to the search task. We investigated whether the irrelevant feature distribution influences learning of the task-relevant distribution and whether observers also encode the irrelevant distribution. Subjects participated in blocks consisting of learning and test streaks. During learning streaks (3-4 trials) orientation and color of each distractor were drawn from a pre-defined distribution (Gaussian or uniform) with constant mean and variance. The target was either distinguishable by color or by orientation based on a pre-defined distance from the distractor mean in feature space. The irrelevant feature of the target was drawn from within the distractor distribution. During test trials targets were probed at particular distances from the mean of the previously learned distractor distribution. The underlying shape of the distractor distribution was assessed through changes in RT as a function of the distance between the target during testing and the distractor mean during learning. Our preliminary results show that properties of the irrelevant distribution impaired the encoding of the relevant one. Data hint towards an asymmetry between the two different features: searching for the oddly-oriented target was more difficult than searching for the oddly-colored target. Moreover, subjects also encode mean and variance of the irrelevant feature distribution during learning but not the distribution shape. Our study demonstrates both an ability to encode information of multiple feature distributions simultaneously but also encoding limitations.

26.364 Variability influences generalization in implicit learning of spatial configurations

Yoko Higuchi[1](yokohiguchi0114@gmail.com), Yoshiyuki Ueda[2], Jun Saiki[3]; [1]Graduate School of Informatics, Nagoya University, [2]Kokoro Research Center, Kyoto University, [3]Graduate School of Human and Environmental Studies, Kyoto University

Implicit learning of spatial configurations facilitates visual search performance—a phenomenon known as contextual cueing. Studies have demonstrated that contextual cueing occurs for variable configurations that items are slightly jittered across repetitions. Humans may be capable of extracting spatial regularity from variable instances and applying the regularity to a new instance implicitly. Generalization should occur when the learned representation and a new instance are similar, but it remains unclear how similarity is computed in implicit learning. The current study investigated whether similarity metrics include the effect of variability by using contextual cueing paradigm. Participants were asked to search for a rotated T target among L distractors, and to judge whether the target was rotated to the left or right. During the learning phase, the similar distractor arrangements were presented repeatedly so that participants could learn the spatial regularity. In Experiment 1, the distractor locations were slightly jittered in some configurations, while they were invariant in the other configurations. We found that learning from the fixed configurations does not generalize to a new similar configuration, while learning from the jittered configurations does. Experiment 2 expands these findings by using Gaussian distributions of different jitter ranges. The results showed that learning generalizes more widely when the jitter range was large than when it was small. These results demonstrated that spatial variability during learning did influence subsequent generalization in contextual cueing, and suggest that similarity between the learned representation and a new instance is computed based on the variability in learning.

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26.365 Attention Restoration Through Virtual Environments

Mohammed F Islam[1](mislam19@fau.edu), Michael J Kleiman[1], Elan Barenholtz[1]; [1]Psychology, Florida Atlantic University

Attentional Restoration Theory (ART) posits that attentional resources are diminished over time with constant engagement in situations requiring directed attention. However, these resources are naturally restored over time (Kaplan, 1995). Moreover, Kaplan and Kaplan (1989) have suggested that a person's attention is more quickly restored in a natural setting (e.g., a park) compared to urban environments. A multitude of studies have confirmed the beneficial effects of natural environments (e.g., Hartig, Mang, & Evans, 1991). These findings also extend to children with Attention Deficit Hyperactivity Disorder (ADHD; Taylor & Kuo, 2009). However, with more than half of the world under urbanization, access to nature is becoming limited (Pearson & Craig, 2014). Virtual reality (VR) may help to alleviate this problem. We aimed to replicate the restorative effects of natural scenes in VR. Participants were tasked to perform an Attention Network Task (ANT) prior to and after being exposed to either a natural (a park) or neutral (a gray room) environment in VR. Participants in the natural scene condition performed ANT much quicker in the post-VR exposure than pre-VR exposure. This effect was not observed in the neutral condition. The findings imply that natural scenes in VR aid in restoring attentional resources and mimic real-world scenes. These findings enable for the manipulation and investigation the different features (e.g., openness) of nature to create an optimized natural scene for attention restoration.

26.366 Automatic prospective and retrospective activation of object representations during statistical learning

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

Although the visual system detects statistical relationships between objects with remarkable efficiency, it is unclear how statistical learning occurs. Here we examine how object representations are activated during statistical learning. In the experiment, participants viewed a continuous sequence of objects at the center of the screen while performing a cover 1-back task during exposure. Unbeknownst to the participants, the sequence contained pairs of objects where one object always appeared before another (e.g., A always appeared before B). At the periphery of the screen, all unique objects in the sequence were presented in fixed locations at all times during exposure. This means that at any given trial, the object in the central sequence was also presented in the periphery, as well as its partner in the pair and all the other objects in other pairs. Participants' eye gaze was tracked throughout exposure. At test, participants chose pairs over foils as more familiar, indicating that they successfully learned the object pairs. Importantly during exposure, we found that when the first object in the pair was presented at the center of the screen, participants looked at its partner (the second object in the pair) in the periphery more than the other objects in other pairs. When the second object in the pair was presented at the center of the screen, participants looked at its partner (the first object in the pair) in the periphery more than the other objects in other pairs. This finding suggests that seeing the first member automatically activates the representation of the upcoming second member in a pair, and seeing the second member automatically activates the representation of the preceding first member. This study not only provides a novel paradigm to measure representation activation during statistical learning, but also elucidates the mechanism of how statistical learning occurs.

26.367 Relative efficacy of global motion versus contrast training early after stroke for recovering contrast sensitivity in cortical blindness

Elizabeth L Saionz[1,2,4](elizabeth_saionz@urmc.rochester.edu), Duje Tadin[3,5], Krystel R Huxlin[4,5]; [1]Translational Biomedical Science Program, University of Rochester Medical Center, [2]Medical Scientist Training Program, University of Rochester Medical Center, [3]Brain and Cognitive Sciences, University of Rochester, [4]Flaum Eye Institute, University of Rochester Medical Center, [5]Center for Visual Science, University of Rochester

Stroke damage to V1 in adult humans causes cortical blindness (CB). Visual discrimination training in chronic (>6 months) CB patients improves their deficit, although recovered vision - particularly contrast

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sensitivity (CS) - remains impaired. Consistent with evidence from sensorimotor stroke that earlier intervention promotes greater recovery, global direction discrimination (GDD) training initiated subacutely (< 3 months) after stroke generates faster, more spatially distributed discrimination improvements compared to identical training in chronic CB. Here, we investigated the effect of training in 9 CBs < 3 months post-stroke. In seven CBs, initial blind field GDD performance was at chance, so they trained on GDD. Surprisingly, 2 CBs had normal GDD performance in their blind fields, so they trained on static orientation discrimination in which contrast was varied to increase difficulty. After daily home training for 3 months, we assessed changes in static (vertical-horizontal orientation discrimination) and motion (left-right direction discrimination) CS using the quick CS function (qCSF) method. In the GDD-training group, initial blind field qCSFs were flat (static and motion). In the contrast-training group, initial blind field static qCSFs were flat but motion qCSFs were not. Following training, the GDD-trained group showed no improvement in static qCSFs but mildly improved sensitivity on motion qCSFs between 0.2-1 cycles/degree (cpd). The contrast-trained group showed no further improvement in motion qCSFs but robust improvement in static qCSFs between 0.2-1.5 cpd. Consistent with this, contrast-trained subjects improved more on clinical visual fields (Humphrey perimetry) compared to GDD-trained CBs, with greater perimetric mean deviation gains (contrast trained: +2.98 dB; GDD trained: +0.716 dB, p=0.024) and deficit shrinkage (contrast trained: -180 deg2; GDD trained: -22 deg2, p< 0.001). In summary, motion perception is occasionally preserved in subacute CBs compared to chronic CBs. While GDD training may improve CS for motion, deliberate contrast training appears necessary to recover static CS.

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26.368 **Binocular fusion during rivalry increases after short term monocular deprivation** Yasha Sheynin[1](jacob.sheynin@mail.mcgill.ca), Sebastien Proulx[1], Robert F Hess[1]; [1]McGill Vision Research, McGill, Dept. Ophthalmology, McGill University, PQ, Canada

Temporarily (120 mins) patching one eye subsequently increases the amount of time spent consciously perceiving the deprived eye's image during binocular rivalry. A recent MRS investigation [Lunghi et. al, 2015] suggests that a reduction in cortical inhibition of the deprived eye may be responsible for the patching-induced shift in ocular dominance. In the present study we investigated whether the occurrence of mixed percepts in binocular rivalry (percepts that require integrated information from both eyes) changes as a result of monocular deprivation. Participants viewed orthogonal (+/- 45°) sinusoidal gratings presented individually to each eye and completed a 5AFC task over the course of a 3-minute block where they indicated whether they were seeing one of the following: (1) an exclusively left-tilted grating, (2) a mostly left-tilted-grating (mixed, left-dominant), (3) a balanced fusion of the two gratings, (4) a mostly right-tilted-grating (mixed, right-dominant), or (5) an exclusively right-tilted grating. Total durations and mean durations were obtained for each percept from a 9-minute baseline session and a 6-minute session after 2 hours of deprivation. Post/baseline ratios (log2) were calculated and used for analysis in a 2-way (time x percept) repeated measures ANOVA. Preliminary data indicate significant time x percept interactions for both total durations and mean durations (Fs = 41, 7; ps < 0.05). Pairwise comparisons show significant patching–induced increases in the proportion and mean duration of mixed percepts dominated by the patched eye (t= -2.8, - 2.6; ps < 0.05) and significant decreases in the proportion of exclusive percepts from the unpatched eye (t = 3.5; p < 0.05). These findings suggest that the ocular dominance shift produced by short-term monocular deprivation is driven by an increase in mixed (binocular) percepts favoring the patched eye, and by a decrease in exclusive (monocular) percepts from the unpatched eye.

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26.369 **Attention cueing and task relevant perceptual learning** Kieu Nguyen[1](knguy044@ucr.edu), Takeo Watanabe[2], George J Andersen[1]; [1]University of California, Riverside, [2]Brown University

The present study examined the role of two types of attention in task relevant visual perceptual learning (TR-VPL): exogenous and endogenous attention. VPL performance was assessed by examining the magnitude of learning to a trained stimulus and transfer of learning to an untrained stimulus. To assess the differential role of attention in VPL, two types of attentional cues were manipulated; endogenous and exogenous. In order to assess the effectiveness of the attentional cue, the two types of attentional cues were further divided into two cue-validity conditions (100% valid, 80% valid). Participants were to discriminate between complex and simple gabors embedded in fixed additive Gaussian noise while contrast of the complex gabor was varied. It was found that for trained stimuli, both endogenous and exogenous attention facilitate TR-VPL as reflected by improved performance from pre-test to post-test. Transfer of training was impacted by cue-validity; with transfer found for those in the 100% cue-validity conditions across both attentional cues.

26.370 **Dyadic perceptual learning of orientation discrimination** Yifei Zhang[1,2,3,4,5](yifei.zhang702@gmail.com), Fang Fang[1,2,3,4,5], Yizhou Wang[5,6]; [1]Peking–Tsinghua Center for Life Sciences, Peking University, Beijing, China, [2]School of Psychological and Cognitive Sciences, Peking University, Beijing, China, [3]IDG/McGovern Institute for Brain Research, Peking University, Beijing, China, [4]Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China, [5]Key Laboratory of Machine Perception (Ministry of Education), Peking University, Beijing, China, [6]National Engineering Laboratory for Video Technology, Cooperative Medianet Innovation Center, and School of Electronics Engineering and Computer Science, Peking University, Beijing, China

Unlike traditional perceptual learning studies in which participants are always trained alone, people usually learn together where social factors like collaboration and competition could influence the learning or training process. Here, we tested whether perceptual learning can be influenced by the presentation of a learning partner, thereafter referred to as dyadic perceptual learning. We trained participants with an orientation discrimination task alone or with a partner for 6 days of 1040 trials. In each trial, two ring-shaped gratings centered at the fixation (outer radius: 4°; inner radius: 1°; contrast: 1.0; spatial frequency: 2 cycles/°) were presented sequentially. Participants were asked to indicate the orientation change from the first to the second gratings. Single learners made only one response and got feedback, whereas paired learners were required to make a second response if their first responses are inconsistent (i.e., they had to decide whether to change their original response based on their confidence in themselves and in their partner). Paired learners communicated through computers, rather than in a face-to-face way. Feedback was also provided to them. We measured discrimination thresholds in the trained orientation and its orthogonal (untrained) orientation for both single learners and paired learners before and after training. The results showed that, in comparison to single learners, paired learners achieved better task performance and their learning speed was faster, suggesting that perceptual learning can be more effective and efficient when trained with a partner. Notably, dyadic perceptual learning also exhibited a hallmark of traditional perceptual learning – orientation specificity. Interestingly, we also found that one's probability of changing his/her original response was positively correlated with the transfer rate to the untrained orientation. These findings suggest that high-level social processes can enhance low-level perceptual learning and provide a more powerful way to improve human perceptual abilities than traditional perceptual training.

26.371 **Coordinated Attentional Training promotes generalization of learning in healthy and MD subjects** Marcello Maniglia[1](marcello.maniglia@gmail.com), Mandy K Biles[2], Kristina M Visscher[2], Aaron R Seitz[1]; [1]Department of Psychology, University of California, Riverside, Riverside, CA, USA, [2]Department of Neurobiology, University of Alabama at Birmingham, Birmingham, AL, USA

Perceptual Learning (PL), experience-induced improvement in perceptual tasks, has shown potential to enhance perceptual abilities in healthy individuals and may provide foundation for rehabilitative protocols in clinical populations. However, PL is often specific to trained features (i.e., type of stimulus, retinal position, eye used during the training etc.). Such specificity is an obstacle to translating PL into effective rehabilitative tools. Here we examine PL in the context of Macular Degeneration (MD), a pathology affecting the retina, which is the leading cause of vision loss in western countries. MD patients must rely on peripheral vision, and do so

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with mixed success. In the best cases, patients learn to use their PRLs for reading and recognizing faces, however many others fail to develop effective PRLs. The factors driving these differences are not well understood. Current rehabilitation techniques, focusing on low-level improvements or oculomotor trainings are often exploratory and there is no standard practice, creating a critical need for evidence-based rehabilitation strategies. Here we present data comparing two training paradigms: a standard perceptual learning paradigm (SPL) and a Coordinated Attentional Training (CAT) that explicitly targets both low-level, perceptual components and cognitive control networks by combining a visual search task, shifts in attention, and multisensory stimulation with standard PL. We hypothesized that CAT would lead to greater learning and generalization in both healthy participants and patients with macular degeneration than standard methods. Initial results show that CAT induced a significant improvement in VA in both healthy and MD participants that trended to be larger than the non-significant change in VA after by SPL. This work suggests that incorporating attention manipulations to standard perceptual learning approaches may improve outcomes.

26.372 **Training to Use Peripheral Vision Does Not Improve Attentional Shifts** Mandy K Biles[1](mkbiles@uab.edu), Ishant S Yadav[1], Brody DeSilva[3], Rong Liu[2], Kristina M Visscher[3]; [1]Department of Psychology, College of Arts and Sciences, University of Alabama at Birmingham, [2]Department of Ophthalmology, School of Medicine, University of Alabama at Birmingham, [3]Department of Neurobiology, School of Medicine, University of Alabama at Birmingham

Several studies have shown that training to use peripheral vision can improve performance on visual tasks involving peripheral stimuli. The mechanism of this improvement is not yet understood. Here we explore, in participants with healthy vision, whether changes in attention may contribute to this improvement. We explored whether peripheral vision training improved shifting of attention, whether it improved the ability to maintain attention to a given location, and whether these effects were specific to the trained part of the visual field. We hypothesized that shift costs (overall performance decrements due to switching covert attention from one location to another) would improve following training. We trained participants to use a pre-assigned peripheral retinal location for a total of twelve hours over several weeks using a gaze contingent training protocol with an artificial scotoma and a visual search task (Liu & Kwon, 2016). We assessed performance on a rapid serial visual presentation task which measures dynamic attention at the trained location and and an equivalent untrained location. After training, the overall accuracy of responses improved significantly. However, training did not lead to decreasing shift costs as hypothesized; in fact, overall shift costs significantly increased with peripheral vision training. One interpretation is that our training protocol improves the ability to maintain attention at a given location, contributing a selective benefit on trials where attention is held at the same location (hold trials). Our data support the idea that our peripheral vision training paradigm improves the ability to maintain attention to a peripheral location, and does not influence the capacity to shift attention from that location. These findings suggest that training to use peripheral vision Improves maintenance of attention to the trained location rather than improving shifting attention from that location.

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26.373 **Non-symbolic division ability mediates the relation between visual number discrimination acuity and symbolic math skill** Emily M Szkudlarek[1](emilysz@sas.upenn.edu), Elizabeth M Brannon[1]; [1]University of Pennsylvania

The ability to discriminate visual number is supported by the Approximate Number System (ANS) and is linked to general math skill (Schneider et al., 2016). However, less is known about an adult's ability to perform visual non-symbolic mathematical operations. Previous work has shown that children can perform division across dot arrays with a symbolic divisor, but it is unknown whether non-symbolic division is possible with a non-symbolic divisor, and how this ability links to symbolic division skills and ANS acuity (McCrink & Spelke, 2016). Here we tested 75 undergraduates (mean age = 20.7, 51 female) on their ability to perform division using a non-symbolic divisor with both dot arrays and numerals. During training subjects calculated with divisors of 2, 5, and 8. During testing subjects had to generalize the division operation across novel divisors (3 and 6). We also measured subjects' ANS acuity and symbolic math skill. Subjects successfully generalized the division operation to novel non-symbolic divisors on both tasks (non-symbolic $t74 = 47.6$, $p < .001$; symbolic $t74 = 68.8$, $p < .001$). Subjects were better at symbolic vs. non-symbolic division ($t74 = -10.3$, $p < .001$), and performance and reaction time on the two tasks were correlated (accuracy $r = .37$, $p = .001$; RT $r = .48$, $p < .001$). Moreover, non-symbolic division accuracy fully mediated the relation between ANS acuity and symbolic division accuracy (bootstrapped indirect effect = -.15, $p = .01$), and partially mediated the relation between ANS acuity and fraction comparison performance (bootstrapped indirect effect = -.14, $p = .03$). These results suggest a close relation between basic visual numerical discrimination ability and the ability to perform non-symbolic mathematical operations in a visual modality. The ability to use non-symbolic number in a math operation mediates the established relation between visual numerical discrimination and math skill.

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26.374 **Sensorimotor effects following exposure to illusory stimuli** Alla Cherniavskaia[1](alla.cherman@gmail.com), Valeria Karpinskaia[1], Vsevolod Lyakhovetskii[2,3]; [1]Department of Psychology, St. Petersburg State University, St. Petersburg, Russia, [2]Movement physiology laboratory, Pavlov Institute of Physiology, Russian Academy of Sciences, St. Petersburg, Russia, [3]Laboratory of Neurosimulation, Russian Scientific Center for Radiology and Surgical Technologies St. Petersburg, Russia

Although the aftereffects of prolonged exposure to visual stimuli have been studied extensively, much less attention has been paid to the effects of prior exposure to illusory stimuli on subsequent motor responses. Lyakhovetskii and Karpinskaia (2017) reported that prior exposure to the classical Ponzo illusion (but not the Müller-Lyer) subsequently affected both right-handed pointing accuracy and the speed of hand movement. The present study examined the effects of prior exposure to illusory stimuli on left-handed movements in order to investigate the possibility of hand-dependent effects. Fifty participants took part in the study. We examined two versions of the Müller-Lyer (out-going fins on the upper or lower shafts) and two versions of the Ponzo (classical and inverted). During the exposure phase, illusory stimuli of different sizes were presented ten times to four experimental groups, a different illusion version to each group. In subsequent test trials, neutral stimuli consisting of two equal length lines (without flanks) were presented thirty times. The control group saw the neutral stimuli at all times. After disappearance of each stimulus, participants moved their left-hand across the touch screen to reproduce the lengths of both upper and lower shafts. We recorded the start and the end points of their hand movements (to measure the strength of the effect of prior exposure) and the duration of each hand movement (to calculate the mean speed). The results of our experiment showed that prior exposure to both versions (classical and inverted) of the Ponzo and one version (out-going fins on the upper shaft) of the Müller-Lyer illusions resulted in distortions to the motor responses of subsequently-presented neutral stimuli as well as increases in the speed of movement of the left-hand. Our findings demonstrate that the effects of exposure to illusory stimuli in the sensorimotor domain are hand dependent.

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26.375 **Exploring a new method to improve facial emotion recognition** Carlijn van den Boomen[1,2](c.vandenboomen@uu.nl), Sjoerd M. Stuit[1], Chantal Kemner[1,2,3]; [1]Department of Experimental Psychology, Helmholtz Institute, Utrecht University, Utrecht, The Netherlands, [2]Department of Developmental Psychology, Utrecht University, Utrecht, The Netherlands, [3]Department of Child and Adolescent Psychiatry, Brain Center Rudolf Magnus, University Medical Centre, Utrecht, The Netherlands

Recognizing emotional expressions is crucial for social interaction. However, individuals can differ greatly in this ability, and those with impairments are known to experience problems in interaction. Difficulties with recognizing emotional expressions may relate to differences in sensitivity to basic visual features. That is, emotional expressions differ in their basic feature-content, for example their contrast energy in specific spatial frequencies and orientations. Importantly, many studies revealed that feature sensitivity can be improved through repeated exposure. Unknown is whether this affects sensitivity for more complex stimuli such as emotional faces. Therefore, we explored the possibility that increasing sensitivity to the basic features that differentiate emotional expressions generalizes to improved facial emotion recognition. In the current experiment, thirty healthy adults participated in a pre-post visual perceptual learning paradigm. During three training sessions, they performed a contrast detection task on a circular noise patch containing the spatial frequency and orientation information that differentiates sad from neutral faces. Note that the noise patches contained no structural information of faces. Both before and after training, detection thresholds were estimated for the training-image and two control images (noise patches based on the feature content that differentiate disgusted and happy faces from neutral faces). Moreover, participants performed an emotion recognition task on sad, disgusted, and happy faces. Results showed increased contrast sensitivity for the noise patches both during and after the training sessions. With respect to generalization to emotion recognition, we show an overall decrease in detection thresholds. However, the decrease was not specific to the trained emotion. Still, emotion recognition performance for sad faces showed a significant correlation to the decrease in contrast thresholds. Overall, this study provides the first indication that training the sensitivity for the basic features that differentiate emotional expressions generalizes to emotional expression recognition.

26.376 **Motor skill consolidation facilitates perceptual learning** Shira Klorfeld[1](shira.s147@gmail.com), Nitzan Censor[2]; [1]Sagol School of Neuroscience, Tel Aviv University, [2]Sagol School of Neuroscience, The School of Psychology, Tel Aviv University,

Practice with perceptual and motor skill tasks results in performance improvements mediated by procedural memory consolidation. In light of recently identified commonalities between perceptual and motor learning (Censor et al., 2012), the goal of the current study was to examine whether motor skill consolidation facilitates perceptual learning, pointing to interactions between the two learning domains. We hypothesized that consolidation of motor skill learning would initiate offline processes that may enable interaction with subsequent perceptual learning. An experimental design combining a saccade motor learning task with a typical visual texture discrimination task (TDT, Karni and Sagi, 1991) was used. On the first day, participants learned to execute a saccade towards a specific retinotopic location. Fixation starting point was randomly varied. Following consolidation of the motor skill and its retrieval, participants learned the visual TDT, in which they maintained fixation while a masked target occupied the same retinotopic location that was used in the saccade task. On the following day, subjects performed the TDT followed by the saccade task. The results showed learning gains in both motor and perceptual tasks. Strikingly, the between-day offline gains in perceptual thresholds were enhanced, compared to practice per se with the visual task. Furthermore, a positive correlation was found between the motor and perceptual improvements. Taken together, these results may indicate an interaction between different learning domains due to synchronized consolidation processes.

26.377 **Cross-cultural differences in perceptual learning** Eirini Mavritsaki[1,2](eirini.mavritsaki@bcu.ac.uk), Stephanie Chua [1], Zoe Kourtzi[3], Maxine Lintern[1], Panagiotis Rentzelas[1]; [1]Department of Psychology, Business Law and Social Sciences, Birmingham City University, [2]School of Psychology, Life Sciences, University of Birmingham, [3]Department of Psychology, University of Cambridge

Cross-cultural studies have shown that independence in individualistic societies is associated with analytic systems of thoughts, whereas collectivistic societies which place greater emphasis on interdependence are generally predisposed to holistic thinking (Masuda & Nisbett, 2011; Bang, 2015). Further, cultural identity has been shown to effect picture perception and cognitive processes (Nisbett & Miyamoto, 2005). For example, Asians were shown to be more sensitive to contextual rather than focal information compared to Americans in a change-blindness task in which observers had to detect either a focal or contextual change within pairs of images (Masuda & Nisbett, 2006). Here, we build on previous work on perceptual learning (Mayhew, Li, & Kourtzi, 2012) and test the role of individualistic vs. collectivistic influences on learning ability. Eighty-three participants of different cultural backgrounds – consisting of Asian (collectivistic) and European (individualistic) students – were asked to discriminate between radial and concentric Glass patterns embedded in background noise. We employed the Singelis' (1994) self-construal scale (SCS) to examine whether differences in task performance due to training were influenced by independent or interdependent cultural values. Visual perceptual learning was evident in both groups; that is, all participants improved in accuracy and reaction times through training. Importantly, Asian participants showed higher performance before and during training than European participants, suggesting an advantage in learning to extract global shapes embedded in cluttered backgrounds. This is consistent with the previously reported tendency of collectivists for global processing under perceptual uncertainty. Our findings provide evidence for the role of cross-cultural influences on visual processes that relate to our ability to improve in making perceptual judgements through training and experience.

Visual Search: Features and cues

Saturday, May 19, 2:45 - 6:45 pm, Pavilion

26.401 **Scene context influences expectations about imprecisely specified search targets** Arryn S Robbins[1](arobbins@nmsu.edu), Michael C Hout[1]; [1]New Mexico State University

When looking for any object from a category (i.e. category search) the variability in appearance between exemplars in a target category influences search performance, with low variability categories leading to shorter reaction times (e.g. Hout et al., 2017; Nako, Smith, & Eimer, 2015). Searchers may not develop (or choose to utilize) a specific search template from highly variable target categories like BOOT compared to low variability categories (wherein exemplars do not vary much in appearance; e.g. BANANA). This study examined how searchers can use expectations from a particular scene to facilitate performance when a target category has too much variability for a searcher to develop a useful template. One group of participants provided our measure of category variability by searching for the category exemplars used in the primary experiment. Categories were thereafter divided into high, medium, and low variability groups, using the average RTs of exemplars within each category. In the primary experimental task, another group of participants received a basic level category word cue (e.g. "BOOT") and searched for a single exemplar from the categories used in the first task. Preceding their search, there was a prime image of a scene (e.g. a ski slope) that was either congruent to the target exemplar (e.g. a ski boot) or incongruent (e.g. a cowboy boot). We found an interaction between prime condition and category variability. When the target category had high variability, participants were faster to respond to targets in the congruent condition than in the incongruent condition. There was no difference between congruent and incongruent trials when the target categories had low variability. The results indicate that context (i.e. a scene) can help searchers develop useful expectations about the appearance of their target in category search, but context is not necessarily beneficial when the target category is homogenous in appearance.

26.402 **We remember what we looked for more precisely when search is difficult** Jason Rajsic[1](jason.rajsic@vanderbilt.edu), Chong Zhao[1], Geoffrey F Woodman[1]; [1]Psychological Sciences, Vanderbilt University

In this study, we tested whether the precision of search templates in memory varies between easy and difficult search. On each trial, participants encoded two square stimuli with randomly selected colors, one of which was subsequently cued to be the target of an upcoming visual search. They then searched among 16 colored squares for a target matching the cued target. After this visual search, participants then had to report the precise color of one of the two items they were remembering using a color wheel. This let us compare the precision of memory for templates (the cued color) to non-templates (the non-cued color). In Experiment 1, all fifteen distractors in the visual search array had different colors, and in Experiment 2, all fifteen distractors had the same color. This let us test whether search difficulty affects memory precision for search templates. Correct reaction times (RTs) and error rates were higher in Experiment 1 than in Experiment 2, demonstrating that color heterogeneity indeed increased search difficulty. More importantly, we found that in Experiment 1 participants had a more precise memory of

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the search template color compared to the non-template color in all search conditions, but in Experiment 2 we found that the precision of template memories did not differ from the non-template memories unless the target appeared in search. These results suggest more difficult visual searches require a more precise template.

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26.403 The influence of search termination with correct "target absent" response Jieun Cho[1](m.jieuncho@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Visual search for a target progresses from a "coarse" to "fine" scale strategy (Over et al., 2007; Godwin et al., 2014). That is, people scan a global layout first, then focus on local areas to find the target. In the current study, participants searched for an oddly oriented bar among other bars (distractors) and reported target presence. Participants had to process overall distractors, because the odd target orientation was defined by the distractor orientations. In Experiment 1, the target orientation was either 45° clockwise or counter-clockwise to the vertical meridian, and it was randomly selected from any orientation in Experiment 2. Thus, participants could not form top-down knowledge about the target orientations in Experiment 2. The difference between the mean distractor orientation and the target orientation was kept constant in every trial. Distractor orientations were either smoothly varied around their mean (smooth distribution) or equally divided into two clusters having extreme orientations (distinct distribution). It has been reported that processing overall distractors is easier when the distractors form a smooth distribution (Utochkin & Yurevich, 2016). In both Experiments, people responded faster in the smooth distribution condition than in the distinct distribution condition. Critically, reaction times were shorter when the current trial was preceded by a correct target-absent trial than by a correct target-present trial. We did not find a significant interaction between the previous trial's target presence and the distribution type. This suggests that participants were using a "coarse" strategy when a search was terminated with a "target absent" response, which may help the global processing of distractors in the following trial. On the other hand, when participants finished a search with a "fine" scale strategy after a successful target detection, it may have cost them to switch to a "coarse" strategy in the following trials.

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26.404 The Influence of Training with One or Two Faces on Dual-Target Face Search Natalie Mestry[1](nmestry@bournemouth.ac.uk), Silke Vos[2,3], Tamaryn Menneer[4], Nick Donnelly[2]; [1]Psychology, Bournemouth University, UK, [2]Psychology, University of Southampton, UK, [3]Experimental Psychology, Ghent University, Belgium, [4]Medical School, University of Exeter, UK

Mestry et al. (2017) reported a dual-target cost when searching for two unfamiliar faces relative to search for one. In dual-target search, participants prioritized one target such that search was better with one face than the other. In the current study, we test if prior training with single face targets or dual-target faces influences the efficiency of dual-target face search in a test phase. Participants completed a training phase with sequential blocks of single-target face search for each face or two blocks of dual-target search for both faces. Following training, participants performed dual-target search in a test phase, followed by two short blocks of single-target search (one for each target). The final two blocks allow insight into the short-term influence of dual-target search on subsequent single-target face search. Response times reduced over phases in all conditions. More importantly, with respect to the effect of training condition on dual-target search, while participants in the single-target training condition were faster overall during training than those receiving dual-target training, those trained with dual-target search responded faster in the test phase. With respect to the short-term influence of dual-target search on subsequent single-target search, the mean response times to faces in the test phase were used to determine preferred and non-preferred faces. By definition the preferred faces were responded to faster than the non-preferred faces in the dual-target test phase. However, and importantly, the same effect of face preference was also found in the two short blocks of single-target face search that followed the test phase. We conclude that (1) if dual-target face search is the task you will ultimately be required to perform, then it is better to be trained in dual-target than single-target search, and (2) the prioritization strategy adopted in dual-target face search has implications for subsequent single-target face search.

26.405 How do differences across visual features combine to determine visual search efficiency in parallel search? Alejandro Lleras[1](Alejandro.Lleras@gmail.com), Jing Xu[1], Simona Buetti[1]; [1]Psychology Department, LAS, University of Illinois

In Wang, Buetti and Lleras (2017), we recently proposed a technique to predict reaction times in efficient search tasks with heterogeneous displays (displays containing various combinations of different types of objects), based on the performance characteristics observed when participants complete simpler search tasks with homogeneous displays (displays where all non-target elements are identical). Here we explored a related question: in the context of an efficient search task, how do separate visual features (e.g., shape, color) combine to create the signal that differentiates a target from distractors? To address this question, Experiment 1 evaluated search efficiency for a target that differed from distractors only along color (cyan target, blue, orange, and yellow distractors); Experiment 2 evaluated efficiency when the target differed from distractors only along shape (half-disc target, circle, triangle, and diamond distractors). Finally, in three subsequent experiments, we created a target by combining the two previous target features (cyan half-disc) and distractors that were combinations of the different color and shape features. The question is: can we predict the logarithmic search efficiency in the mixed feature conditions, based on the log efficiency observed in Experiments 1 and 2 (single feature conditions)? We compared predictions from a categorical feature guidance model, and our contrast-signal model of parallel search (where contrast signal from orthogonal feature dimensions combine in Euclidian fashion). The results showed an actual improvement in search efficiency that was much larger than predicted by either model, suggesting that the contrast between target and distractors increases in an over-additive fashion when multiple visual features are combined.

26.406 Factors that reduce grouping also decrease the collinear masking effect in visual search Li Jingling[1](jlli@mail.cmu.edu.tw), Yen-Ting Liu[1]; [1]Graduate Institute of Biomedical Sciences, China Medical University

Salient items are usually easier to search. However, our previous work established an interesting phenomenon that a salient target was more difficult to search than that in the background. The phenomenon was observed in a search display where the salient region was formed by collinear grouping, thus we called it the collinear masking effect. This study aimed to test whether factors reduce grouping can also decrease the collinear masking effect. Three experiments was carried out to test conditions increasing spacing, scale, or number of items in the background, respectively. The results confirmed that the collinear masking effect indeed reduced when grouping strength was weaker. Another control experiment confired that the reduction of the collinear masking effect was not due to expending eccentricity with the increasing spacing or scale, neither due to different orientation of the target. Our data support the idea that the collinear masking effect was associated with perceptual grouping. Further evidence is needed to investigate why such a salient grouping can mask a local target.

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26.407 Compound statistical learning of target selection and distractor suppression Oscar Ferrante[1](oscar.ferrante@univr.it), Elisa Santandrea[1], Leonardo Chelazzi[1,2]; [1]Department of Neuroscience, Biomedicine and Movement, University of Verona, Italy, [2]Italian Institute of Neuroscience (INN), Verona, Italy

In visual search, attention can be guided on the basis of statistical regularities in display composition learned through experience – a form of statistical learning (SL) in the attention domain. Specifically, higher priority is conferred to display locations that more often contain the target, relative to locations with rare targets. Likewise, lower priority is conferred to locations that more often contain a salient distractor, relative to locations with rare distractors. In a recent study, we found cross-talk between these two

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forms of SL, with target SL influencing distractor interference, and vice versa, which is compatible with the notion that both forms of SL modify priority maps of space. Here we tested this idea further by asking how the system would be affected when target and distractor SL are tipped one against the other. Specifically, we had distinct display locations where the probability of both target and distractor were high or, respectively, low. Based on prior evidence, high target frequency should increase priority at the corresponding location, but high distractor frequency at the same location should reduce priority. Similarly, low target frequency should decrease priority at the corresponding location, but low distractor frequency at the same location should increase priority. The results showed clear item-specific modulation of performance at the two critical locations: target selection was enhanced at the high vs. low target-probability location; however, at the same time, the distractor cost was greater at the low vs. high-distractor probability location. Furthermore, the two effects were anti-correlated, indicating a different susceptibility to the two forms of SL across participants. These findings indicate that at least to some extent target and distractor SL can co-occur at the same location, even when they dictate opposite changes in priority. This indicates some independence of the underlying neural mechanisms, likely reflecting a feature-based component.

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26.408 **Long-term learned values of visual objects guide involuntary gaze bias in no-goal condition** Hyeji Z Kim[1,2](pluma17@gmail.com), Joonyoung Kang[3,4], Sue-Hyun Lee[3,4], Hyoung F Kim[1,2]; [1]Center for Neuroscience Imaging Research, Institute for Basic Science (IBS), Suwon 16419, Republic of Korea, [2]Department of Biomedical Engineering Sungkyunkwan University (SKKU), Suwon 16419, Republic of Korea, [3]Department of Bio and Brain Engineering, College of Engineering, Korea Advanced Institute of Science and Technology, [4]Program of Brain and Cognitive Engineering, College of Engineering, Korea Advanced Institute of Science and Technology

Gaze direction is not only decided voluntarily by the goal or intention but also affected involuntarily by visual salience, novelty and acquired experience with no specific goal and no feedback. Previous monkey study (Kim and Hikosaka, 2013) showed that long-term learned values of visual objects guide saccades in automatic manners. Then, do the long-term learned values also guide saccades of human? If so, which brain regions represent the long-term learned values? To address these questions, 26 human participants learned object-value association for 5 days. Three groups of fractal objects were associated with different monetary values: good (gain), bad (loss), and neutral (neither gain nor loss). Pairs of objects with different values were simultaneously presented, and participants chose higher valued objects to maximize monetary reward. Participants achieved the maximum performance after 4 days, indicating that they gradually learned the value-guided choice behavior. Before the first and 5-day of learning, participants performed a free gazing task in which nine learned objects were simultaneously presented, and participants freely looked at them for 8 seconds without any outcome. After 4 days of learning, the number of first gaze and gaze frequency to learned good objects were increased (+0.8077 times/session; +4.65 times/trial) but the view durations of learned bad and neutral objects were reduced (-45.29ms/trial; -48.85ms/trial). To identify the brain structures guiding involuntary gaze, fMRI data were acquired before and after the learning. We found that subjects showing better performances in free gazing task had greater activation differences (good-bad contrast) in the caudate tail BOLD after long-term learning. This suggests a role of the caudate tail in long-term value memory-based gaze bias. These results indicate that the past learned values guide involuntary gaze in no-goal condition, and the human caudate tail might be involved in the historical value process for the gaze bias.

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26.409 **Study of Visual Search in 3D Space using Virtual Reality (VR)** Tandra Ghose[1](tandra@berkeley.edu), Aman S Mathur[2], Rupak Majumdar [2]; [1]Department of Psychology, University of Kaiserslautern, Germany, [2]Max Planck Institute for Software Systems, Kaiserslautern, Germany

As VR gains mainstream traction and is adopted for more serious use-cases such as remote monitoring and troubleshooting, a thorough study of perception over such devices becomes important. An advantage that VR has over its 2D counterpart is the large virtual space. However, it needs to be empirically determined how visual search characteristics derived from traditional 2D visual search experiments (~50 objects) scale to immersive 3D scenarios with more numerous objects (~1000). To study this, we designed the classic feature and conjunction search experiment in VR, modelling virtual space using a spherical coordinate system centered at the VR headset's initial position. The target was presented in one of 32 equally sized regions blocked with 45 degree increments in radial angle and elevation. The target was a red cube embedded in 96, 480, 768, or 1024 distractors that were equally distributed among the 3D regions. Distractors were either green cubes (feature search) or red spheres and green cubes (conjunction search). The task was to find the target as quickly as possible using head and body movements. We studied slopes of reaction times with respect to number of distractors for each of the 32 regions. Based on data from 25 participants, overall, the typical pattern of slope of feature and conjunction search was observed. For regions directly in front of the participants, reaction times were faster for the left versus right visual field. Even regions behind the observer followed similar trends as regions in front. Search in atypical regions, such as close to the toes or directly above demonstrated haphazard characteristics. Though these findings seem robust, we found that occlusion can be a nuisance variable in such search tasks.

26.410 **Characterizing Cue Specificity in Visual Search Performance** Maria Nikiforova[1](vision.nikifo@gmail.com), Melchi Michel[1]; [1]Psychology, Rutgers University

Visual searches for targets indicated by picture cues consistently result in better performance than those in which targets are indicated using word cues, with no definite answer as to why. (Wolfe, Horowitz, Kenner, Hyle & Vasan, 2004; Bravo & Farid, 2009; Schmidt & Zelinsky, 2009). One explanation for this phenomenon is that the two cue modalities provide different amounts of information. Picture cues provide specific information about the target features, while word cues evoke a vague distribution of possible target features. Our study tests this explanation by quantitatively varying the feature specificity of picture cues. If increased specificity explains the search advantage of picture cues, then reducing cue specificity should reduce performance. Participants performed a conjunction search for an oval or rectangle of a particular color in an array of similar elements after briefly observing a cue indicating the target, which was always present. The search cue itself was a picture, word, or nonspecific cue. Picture cues could exactly match the target, or be drawn from a distribution centered on the target's feature values. Picture cue specificity was manipulated by changing the feature variance of the picture cue color distributions, which were highly narrow, equivalent to those applied to word cues, or wider. We characterized the specificity of word cues using a hue selection task like that of Bae, Olkkonen, Allred, Wilson & Flombaum (2014). Search performance was measured using reaction time, which increased as picture cue specificity decreased. Overall these results are consistent with specificity being the source of picture cue search performance.

26.411 **Two targets, held in memory, can guide search; four targets cannot.** Farahnaz A. Wick[1,2](farahnaz@gmail.com), Gabriel Kreiman[1,3], Jeremy M. Wolfe[1,2]; [1]Harvard Medical School, [2]Brigham and Women's Hospital, [3]Boston Children's Hospital

When you are looking for your car keys, umbrella and that favorite coat, how do you decide where to look next with all these items in your memory? In the experiments reported here, observers memorized grayscale pictures of 1, 2 or 4 targets and then searched for any one of these targets in a search array of 6 items. Observers responded with a keypress, indicating whether a target was present or absent. A single target appeared on 50% of the trials. Eye movements and keypress reaction times were recorded. The accuracy was >95% when memory load was 1 or 2 and >90% when memory load was 4. Keypress reaction times increased with memory load indicating that search became more difficult as more items were held in memory. If observers fixated on items at random, they would require 3.5 fixations on average (assuming sampling without replacement). On target present trials, when the memory load was 1, only 1.9 fixations were required, showing that fixations were "guided". With

a memory load of 2, average fixation count was 2.2, still significantly less than 3.5. However, with a memory load of 4, 3.2 fixations were required, not significantly different from random. These results suggest that visual search can be guided by features from two targets simultaneously, despite the distinct shape features present in those targets. As the number of targets increase, we infer that the number of different features becomes too large for effective guidance, introducing a strong constraint for computational models of visual search. We develop a biologically inspired model of visual search constrained by these experimental observations to investigate the top-down mechanisms that modulate the attentional map in hybrid search tasks and directly compare the model versus the psychophysics measurements.

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26.412 **Experience with noise does not prevent the formation of Contextual Cueing** 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 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 (Chun, & Jiang, 1998). However, if participants are first introduced to a random visual search (i.e., noise), a contextual cueing effect is not observed (Junge, Scholl, & Chun, 2007). It was therefore suggested that the absence of regularity in early stages of training creates a "shutdown" that prevents participants from learning regularities later on (Junge et al., 2007). We revisit this argument, with two groups of participants that first performed a visual search task with only structured, or only random trials before a contextual cueing condition was introduced. For the first half of the experiment the task was either random (random-first group, n=30) or completely structured (consistent-first group, n=30). In the second half of the experiment, both groups were implicitly introduced with the contextual cuing condition, in which consistent and random conditions were randomly intermixed. Replicating previous studies, a robust contextual cueing effect was observed for the consistent first group. This effect was observed immediately after switching from completely structure to mixed conditions. However, a contextual cueing effect was also observed in the random-first group. This effect only emerged in the last few blocks of the experiment, and was smaller relative to the consistent-first group. Our results question the current view that performing the task randomly creates a shutdown of statistical learning. We discuss the differences between the present and previous work, and the specific conditions that enable the system to pick up regularities when these are introduced following a period of random trials.

26.413 **Long time no see: enduring behavioral and neuronal changes in feature conjunction learning 3 years after training** Sebastian M Frank[1](sebastian.m.frank.gr@dartmouth.edu), Mark W Greenlee[2], Peter U Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]Institute for Experimental Psychology, University of Regensburg

Successful learning should lead to enduring improvements that outlast the period of training and that ideally persist for a life-time. Here, we show that for a certain class of visual stimuli, conjunctions of simple motion features, learning leads to changes that endure for years beyond the period of training. Moreover, we show that these enduring behavioral learning effects are associated with lasting changes in brain activity. A group of participants was trained on a visual search task for motion trajectories. Specifically, participants were trained to detect the presence of a "v"-shaped target trajectory among inverted "v"-shaped distractor trajectories. Participants performed twelve training sessions (about 15 min each) on separate days. Over the course of training performance improved dramatically. The first and last of these training sessions were carried out during functional MRI. The MRI-results suggested that the representation of the target improved over the representation of the distractor stimulus in early visual cortex (V1-V3) after training. In order to test the long-term stability of these training-induced behavioral and neuronal changes, participants were recruited for a retest on the trained task three years after the end of their original training. We observed that performance improvements were highly stable over time. Participants performed as if no time had passed between the end of training and the retest after three years. A similar long-lasting effect of training was observed for the neuronal representation of the stimuli in early visual cortex. Together, these results suggest that feature conjunction learning may lead to changes in performance and brain activity that last for years beyond the period of training and that potentially endure for a life-time (see Frank, Greenlee, & Tse, 2017, Cerebral Cortex, doi: 10.1093/cercor/bhx039).

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26.414 **Implicit measurement of the own-race bias using the visual search paradigm** Sandra C Utz[1](sandra.utz@uni-bamberg.de), Sabrina Weigand[1], Claus-Christian Carbon[1,2]; [1]University of Bamberg, [2]Bamberg Graduate School of Affective and Cognitive Sciences (BaGrACS)

The phenomenon of the own-race bias implies the tendency to recognize faces of the race someone is most familiar with, i.e., of their own race, faster and with higher accuracy (e.g., Meissner & Brigham, 2001; Malpass & Kravitz, 1960). To measure this tendency more implicitly, the visual search paradigm can be used, where participants have to detect the presence or absence of a target face under a certain amount of distractors (e.g., Lipp et al., 2009; Sun et al., 2013). However, studies so far cannot consistently show a bias for own race faces, probably due to non-standardized /not adequately-matched stimulus material. The present study also examines the own-race bias employing a visual search paradigm, namely a feature search task: Caucasian participants had to decide as quickly and as accurately as possible whether a target face is present (e.g., a white target face among black distractor faces) or absent under several distractor faces. Results showed that participants performed in general significantly better, i.e., made more correct answers, if faces were white compared to when faces were black. Analysis of reaction times showed that for white faces participants were significantly faster when a target face was present compared to when it was absent. For black faces, there was no difference in reaction times between target present or absent trials, i.e., participants needed the same amount of time to decide if a black target face was present or a white target face was absent. Only in absent trials, participants needed more time for white compared to black faces. Therefore, it seems to be harder to detect the absence of a black target face than to detect the absence of a white target face, i.e., a face of participants' own race. Overall, results seem to confirm the bias for own race faces.

26.415 **Hybrid Foraging Performance is Related to Fluid Intelligence** Adrián R. Muñoz-García[1](adrian.munnoz@uam.es), Matthew S. Cain[2], Jeremy M. Wolfe[3], Beatriz Gil-Gómez de Liaño[1]; [1]Universidad Autónoma de Madrid, [2]U.S. Army, Natick Soldier Research & Development Center, [3]Harvard Medical School-Brigham & Women's Hospital

It is known that Executive Functions (EF) are related to Fluid Intelligence (e.g. Miyake et al., 2001). However, although attentional control is a key factor in executive functions, it is not that clear whether Gf mediates in Visual Search tasks (e.g. Kane et al., 2006). Hybrid foraging search is a visual search task in which an observer looks for multiple instances of several types of targets held in memory (Wolfe, et al., 2016). Hybrid Foraging involves inhibition and attentional control as well as switching and cognitive flexibility. Thus, Hybrid Foraging would seem to put more demands on Executive Function than typical search tasks. We asked if, consequently, Hybrid Foraging performance would be related to Fluid Intelligence (Gf). Gf was estimated in eighty-three participants using the APM Raven test. They were also tested in three Hybrid Foraging tasks: Feature, Conjunction, and difficult Letter foraging. For example, in the letter task, observers collected 'b' and 'p' targets amongst 'q' and 'd' distractors. All items were in motion to prevent simple left to right, top to bottom collection. Results show that Gf is correlated with Hybrid Foraging performance: error rates were lower when APM scores were higher both for Letter ($r=-.40$; $p< .001$) and Conjunction foraging ($r=-.34$; $p=.002$), but not for Feature/easy search. Also, for Conjunction search average search RTs were faster when APM scores were higher ($r=-.30$; $p=.007$). Jointly error rate and RTs, we find that efficiency increases as Gf increases. Finally, about 'runs-switches' of target selections, although RTs are still shorter in general as Gf increases, the interactions are not significant among factors, showing that strategies of "run/switch" searches seem to be similar for all Gf levels. The present results suggest that Hybrid Foraging tasks may be an interesting paradigm to investigate the relationships between attentional capacity and executive functions.

Motion: Higher order

Saturday, May 19, 2:45 - 6:45 pm, Pavilion

26.416 How unconscious retinotopic processing influences conscious non-retinotopic perception

Oh-hyeon Choung[1](oh-hyeon.choung@epfl.ch), Marc M. Lauffs[1], Haluk Öğmen[2], Michael H. Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland, [2]Department of Electrical and Computer Engineering, University of Denver, CO, USA

Unconscious processing can significantly affect conscious processing. For instance, unconscious processing of a masked prime can facilitate processing of an afterward presented stimulusIt is usually thought that the unconscious prime activates motor-processing. For this reason, reaction times are speeded in congruent and slowed down in incongruent conditions. Here, we show that unconscious processing can also strongly influence conscious processing in the Ternus-Pikler display, in which three black disks move horizontally in concert. In addition, each disk contains a white dot, which move either vertically or horizontally. Still, in the center disk a non-retinotopic rotation is perceived, which is a combination of the retinotopic left-right and up-down motions. These retinotopic motions are unconscious. When we, in a second experiment, present retinotopic rotations in the disks, still non-retinotopic rotation is perceived. When the retinotopic rotations are congruent with the non-retinotopic one, there is only a slight improvement in performance with the non-retinotopic rotation. However, when the motions are incongruent, performance strongly deteriorates. The more incongruent retinotopic rotations there are, the stronger the deterioration is. Thus, contrary to mask priming, unconscious information influences conscious perception only in incongruent conditions. In addition, motor response activation cannot explain the results since responses were not speeded. Hence, it seems unconscious processing can influence conscious perception in different ways. A simple mismatch veto model explains these results.

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26.417 Temporal integration of speed change in motion perception

Abigail RI Lee[1](aril@st-andrews.ac.uk), Justin M Ales[1], Julie M Harris[1]; [1]School of Psychology and Neuroscience, University of St. Andrews

Speed change discrimination, where a stimulus containing a step change in speed is discriminated from a constant speed stimulus, is more difficult than discriminating between two separate stimuli with different constant speeds (Lee, Ales & Harris, J Vis., 17(10):416, 2017; Monen & Brenner, Perception, 23(6):681-690, 1994; Snowden & Braddick, Vision Res., 31(5):907-914, 1992). Here, we explore one possible explanation for this: if there is no temporal separation between two presented speeds, there could be temporal integration of motion signals, making it harder to discriminate between the speeds. 8 naïve observers completed a speed change discrimination task in which a moving line either had a step increase or decrease in speed. The task was to indicate whether the stimulus speed increased or decreased. Three different temporal separation conditions were used. In the first, the moving line instantaneously changed speed at some point during its motion (0s temporal separation condition). In the other conditions, the line disappeared for either 0.5s or 1s, then reappeared in the same location and continued along its trajectory at the new speed (0.5s temporal separation and 1s temporal separation conditions). We explored two ranges of speeds, with initial speeds of either 2deg/s ('slow') or 20deg/s ('fast'). Thresholds, as measured by Weber fractions, were not significantly different across temporal separation conditions using fast speeds (thresholds ± SEM, 0s: 0.138 ± 0.012; 0.5s: 0.144 ± 0.008; 1s: 0.136 ± 0.008). This was also found for conditions using slow speeds (thresholds ± SEM, 0s: 0.196 ± 0.038; 0.5s: 0.183 ± 0.027; 1s: 0.165 ± 0.018). Adding temporal separation therefore does not decrease the difficulty of the speed change discrimination task. These results suggest that temporal integration of speeds alone is not responsible for making speed change discrimination a difficult task.

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26.418 Border enhancing flicker effect in form-from-motion test

Sara Giovagnoli[1](sara.giovagnoli@unibo.it), Roberto Bolzani[1], Tony Pansell[2], Mariagrazia Benassi[1]; [1]Department of Psychology, University of Bologna, [2]Department of Clinical Neuroscience, The Karolinska Institute, Stockholm

The form-from-motion tests are often done by means of dots moving in two different, sometime opposite, directions inside and outside the form. Generally, the dots disappear when they cross the form border and reappear in some other place depending on the previous position to maintain the same dots density. Grossman and Blake (1999), to avoid the border enhancement due to the luminance flickering, set up a stimulus based on dots not disappearing on the form border. The stimulus is done by dots moving diagonally outside the form and changing randomly to a ±30° deviated direction when the dots enter a virtually defined form. Experiment 1 To check the accuracy difference between the border crossing and non-crossing condition, 21 subjects are tested using two stimuli: one like the Grossman stimulus and the other having the same characteristics but not allowing the dots to cross the border. They disappear and reappear outside or inside the form depending on the original place. The difficulty level is changed decreasing the number of the dots moving in deviated direction inside the form. Results 1 The results showed a significantly different accuracy ($p < .001$) at all the difficulty levels with a better accuracy in non-crossing condition. Experiment 2 To see if the border flickering effect alone can elicit the form perception, a second experiment is done on the same subjects with the stimulus made by diagonally moving dots both inside and outside the form but disappearing when they cross the border. Results 2 All the subjects have been able to correctly detect the form at least in the lowest difficulty level. Conclusion A form-from-motion test using dots disappearing on the border does not measure the form perception due only to the motion contrast effect but that due also to the border flickering effect.

26.419 Global motion perception is faster but less accurate with dark random-dot kinematograms

Lanya Tianhao Cai[1](tcai@sunyopt.edu), Benjamin T Backus[1]; [1]Graduate Center for Vision Research, SUNY College of Optometry

Primate vision exhibits a "light-dark asymmetry" originating from ON and OFF channels in the retina. Neurophysiology and psychophysics show a processing speed advantage for darks (Komban et al. 2011 J Neurosci). We looked for a corresponding "dark benefit" in global motion perception. Performance of global motion perception in random-dot kinematograms (RDKs) can be assessed in terms of reaction time and accuracy. We hypothesized that a dark benefit in early vision could lead to better efficiency for dark dots as compared to light dots, in the form of a shorter reaction time or a higher accuracy, or both. We measured speed-accuracy trade-off functions (SATF) in 3 contrast polarity conditions of RDKs: white dots on a gray background (W/G), black dots on a gray background (B/G), and gray dots on a black background (G/B), and expected to see a dark benefit with black dots on a gray background. Viewing of signal and noise dots was monocular or segregated, to test whether binocularity interacts with dot polarity. Indeed, we found a slightly shorter latency in the SATF's deviation from chance for black dots. However, this dark benefit was not general: performance was not better for black dots. These findings suggest that the processing speed advantage for darks is preserved at the level of global motion perception, but that response properties of the OFF pathway limit that pathway's spatiotemporal summation window in early vision, which compromises motion discrimination performance.

26.420 Flicker-Induced Induced Motion

Gennady Erlikhman[1] (gennaer@gmail.com), Sion Gutentag[1], Christopher Blair[2], Gideon P Caplovitz[1]; [1]Department of Psychology, University of Nevada, Reno, [2]Department of Psychology, Eastern Oregon University

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We describe a visual illusion in which a stationary, flickering disc appears to move when presented simultaneously with other flickering discs. We refer to this effect as flicker-induced induced motion (FLIIM). FLIIM occurs regardless of whether the discs have soft or hard contours, but only when there is more than one flickering object. Across three experiments, we examined (1) the optimal flicker rate at which motion was seen, (2) the strength of the effect as a function of eccentricity, and (3) whether the effect was present when the flicker is an isoluminant color change. In all experiments, four discs were presented on the screen for 1 s. Three of the discs were displaced by a small amount in a random direction each frame, while the fourth remained stationary. Participants attempted to identify the stationary disc. In all experiments, discs alternated between black and white at rates of 2-14 Hz. In a control, 0 Hz condition, the discs did not change color, but three of the four still moved. The effect was stronger (detection of the stationary disc was worse) when the discs were presented in the periphery (Exp. 1), compared to when they were presented foveally (Exp. 2). FLIIM occurred equally strongly for black-white and isoluminant color changes (Exp. 3). Across both kinds of changes and eccentricities, accuracy was worst at a 2 Hz flicker rate and gradually improved up to 8-9 Hz, at which point it was similar to the control condition. The presence of a static, non-flickering fixation point suggests that the effect is not due to ambiguity in the frame of reference.

26.421 **Motion Entrainment in the Periphery** Neal Dykmans[1](n-dykmans@ucsd.edu), Stuart Anstis[1]; [1]Department of Psychology, University of California San Diego

A field of dense random dots that makes a series of small jumps is veridically seen in apparent motion. If the jumps exceed a distance Dmax (Braddick, Vision Res. 1974; Dykmans and Anstis, VSS 2015) the observer loses track of which dot is which and sees only random twinkling motion (dynamic visual noise). Dmax increased steadily with eccentricity, being 0.2° at an eccentricity of 9°, rising to ~3° at an eccentricity of 65°. Thus an orbiting motion that looked like random twinkling in the fovea (jump > small Dmax) could clearly be seen to orbit in the periphery (jump < large Dmax). We have found that if a moving patch (jump < Dmax) was put next to a twinkling patch (jump > Dmax), the motion captured or entrained the twinkle and both patches appeared to move in unison. We used two adjacent rectangular patches, or a moving disk surrounded by a twinkling annulus, or conversely a twinkling disk surrounded by a moving annulus. To avoid motion streaks, the motion was in circular orbits instead of linear. Results: Entrainment increased markedly with increasing eccentricity. In the far periphery (65°), an inner orbiting disc appeared to entrain outward into the surrounding twinkle, its perceived radius increasing by as much as 24%. For the opposite condition, in which an annulus of orbit surrounded twinkle, at 65° an outer annulus of orbit (15% total area) entrained the remaining inner 85% of twinkle.

26.422 **Violation of projective consistency in structure-from-motion: a role for skin motion?** Xiaoli He[1,2](cryingathena@gmail.com), Manish Singh[1,2], Jacob Feldman[1,2]; [1]Department of Psychology, Rutgers University - New Brunswick, [2]Center for Cognitive Science, Rutgers University - New Brunswick

SFM studies have shown that observers can have vivid 3D percepts in dynamic dot displays that are projectively consistent with 3D rotation. However, under certain conditions, observers can also perceive 3D structures that are not projectively consistent with image motion (Ramachandran et al. 1988; Froyen et al., JOV2013; Tanrikulu et al., JOV2016). In previous work (He et al., VSS, 2015, 2016, 2017), we have investigated the violation of projective consistency in SFM in terms of both dot motion and occluding contour geometry. We found that observers perceive 3D shape despite the lack of projective consistency. One alternative explanation of this apparent violation is that, in the projectively-inconsistent cases, observers perceive 3D structure, but the dots are seen as sliding along the 3D surface, rather than rigidly attached to it. Under this account, percepts of skin motion should increase systematically with the degree of projective inconsistency. Stimulus shapes consisted of two vertically oriented sine curves with different relative phases, generating a transition from symmetric to parallel. The occluding contour remained fixed, so that only the symmetric shape could be projectively consistent with 3D rotation. Dots moved horizontally, with speed profiles varying from cosine motion (projectively consistent with rotation in depth) to constant speed. Observers judged whether each display looked three-dimensional and, if so, whether the dots looked like they were sliding along the 3D surface. The pattern of 3D responses replicated our previous findings: 3D percepts were reported > 75% with only 40% cosine motion and this pattern was barely different for symmetric vs. asymmetric shapes. However, no consistent pattern could be discerned across observers regarding the skin-motion percept. While skin motion is an interesting and largely ignored percept that deserves to be investigated on its own, it seems unlikely to provide a viable account of the violation of the projective-consistency constraint.

26.423 **Visual psychophysics on the web: open-access tools, experiments, and results using online platforms** Sivananda Rajananda[1,2](vrsivananda@gmail.com), Megan A.K. Peters[1], Hakwan Lau[2,3,4], Brian Odegaard[2]; [1]University of California-Riverside, Department of Bioengineering, [2]University of California-Los Angeles, Department of Psychology, [3]University of California-Los Angeles, Brain Research Institute, [4]Hong Kong University, Department of Psychology Abstract

In the last several years, web-based experiments with visual stimuli have become increasingly common as researchers have utilized online paradigms to facilitate fast data collection with large samples. However, few open-access tools exist for conducting rigorous visual psychophysical studies on the internet. Here, we present new tools to enable vision science in web browsers, as well as sample experiments and results which demonstrate their viability. These tools include several methods to estimate psychophysical threshold parameters that run entirely in JavaScript/CSS/HTML, including the PEST adaptive staircase procedure and the Confidence Signal Detection model (Yi & Merfeld, 2016), which leverages confidence judgments to estimate thresholds with a small number of trials. We also present the first open-access random-dot kinematogram which runs entirely in web browsers and includes parameters to customize coherence levels, aperture shape, dot size, and other features. Our initial experiments on human motion perception demonstrate three important findings: (1) with our tools, motion threshold parameters estimated from online subjects are comparable to those estimated in controlled laboratory environments; (2) our web-based implementation of new methods facilitates faster threshold estimation than traditional methods; (3) data from online subjects indicates these participants are much more demographically diverse than studies from university laboratories. We have also developed new paradigms for testing peripheral color perception online, and results show that observers often overestimate how saturated parafoveal visual stimuli truly are. Finally, we will discuss results from recent investigations investigating differences between foveal and parafoveal motion perception. Together, these experiments demonstrate that despite sacrificing a degree of experimental control, rigorous web-based psychophysics is quite possible, as our initial results provide promising evidence to motivate future development of online tools for visual science.

26.424 **Moderate Influence of Target Size Variability on Visual Gravity Judgements** Björn Jörges[1](bjoern_joerges@hotmail.de), Lena Slupinski[2], Joan López-Moliner[1]; [1]Institute of Neurosciences, University of Barcelona, [2]Institute of Sport and Exercise Sciences, University of Münster

A strong earth gravity prior lends an important contribution to many functions regarding perceptuo-motor skills like reaching, catching or throwing (Jörges & López-Moliner, 2017). When earth-discrepant gravities are presented (f. e. visually in Virtual Reality), humans can not rely on this prior and need to extract the gravity value from the visual scene. A previous experiment suggests that, for parabolic motion, both Visual Angle and Elevation Angle information play a role in this computation. In addition to these online cues, it would be beneficial for observers to establish and rely on a representation of target size. To determine whether this is the case, the present experiment investigates how variability of object size influences visual gravity judgments for parabolic motion. To this end, participants (n = 12, 2 excluded) were asked to judge in a two-alternative forced-choice paradigm which of two parabolic motions had the higher underlying gravity. The test parabola could be governed by one of seven gravities (0.7 g – 1.3 g), while the reference parabola was always governed by 1 g. Their order was randomized. Both could have one out of two initial vertical velocities (3.7 or 5.2 m/s) and one out of two horizontal velocities (6 or 8.3 m/s). Furthermore, we manipulated variability of ball

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size (drawn from a Gaussian distribution with a mean of 0.033 m and a SD of 0.02 m or 0.005 m, respectively presented in blocks). Participants displayed a slight decrease in sensitivity in the high variability condition and a strong bias to judge smaller targets as being affected by higher gravities. Furthermore, sensitivity of some participants increased when the displayed ball size was within 10 % of the mean ball size. We conclude that an accurate representation of object size has some beneficial effects for the extraction of gravity from parabolic motion.

26.425 **Priming staircase motion: evidence of a motion-pattern priming mechanism** Nathan H Heller[1,2](nhheller@ucsc.edu), Maxwell Schooley[1], Sean McDougall[1], Nicolas Davidenko[1]; [1]University of California Santa Cruz, Department of Psychology, [2]University of California Santa Cruz, Department of Applied Mathematics and Statistics

Ambiguous apparent motion stimuli have long been used to study the effects of motion priming. It is well established that, at certain frame and prime durations, attending to a unidirectional drifting motion-pattern can constrain the correspondence solution of subsequently viewed ambiguous frames. In a recently published study (Davidenko et al., 2017) we showed that priming with a bidirectional rebounding motion-pattern at 2.5Hz produces a similar effect in sufficiently ambiguous stimuli: persistent rebounding illusory apparent motion was reported as lasting for M = 6.2 frames (2.48 seconds) on average. The ability to prime rebounding motion could be interpreted as evidence for a high-level mechanism that operates by 1) encoding a two-step motion-pattern (i.e. left-right-left-right), 2) maintaining the temporal order of each step during ambiguous frame transitions, and 3) deploying selective attention during each frame transition such that the encoded pattern is reinstantiated. However, there is also evidence that illusory rebounding motion is a kind of default percept (Verstraten, Cavanagh, & Labianca, 2000; Hock, Park, & Schöner, 2002; Hsieh, Caplovitz, & Tse, 2005). For example, if neural populations that are tuned to opposing directions along the same axis (i.e. left and right) are related through inhibitory interactions, any consistent activation of these populations may result in a type of rivalry effect that maintains the rebounding pattern. In the present study, we dissociate these two explanations by priming with a non-rebounding two-step motion-pattern: staircase motion (e.g. up-right-up-right). We show that, as with drifting and rebounding patterns, exposure to a slowly moving staircase motion-pattern (1.5Hz) constrains subsequently viewed frames of refreshing random dot arrays to maintain the illusory staircase motion-pattern (M = 5.9 frames, 3.87 seconds). These results provide further evidence for the existence of a priming mechanism operating at the level of motion-pattern encoding.

26.426 **Stimulus driven attention-shift as a driver of apparent motion perception** Zijiang He[1](zjhe@louisville.edu), Wei Wei[1], Chao Han[2], Teng Leng Ooi[2]; [1]Dept. Psychological and Brain Sciences, University of Louisville, [2]College of Optometry, Ohio State University

Top-down attention can affect apparent motion (AM) of sequentially presented static tokens (e.g., Wertheimer, 1912; Kohler et al, 2008). It is also likely that the sequential token presentations can drive attention to shift from one location to another. It is thus reasonable to hypothesize that such stimulus-driven attention-shift itself is a driver of AM perception. We tested this hypothesis using a motion adaptation protocol, where we manipulated the adaptation display (adapter) and attention status for 2 minutes and then measured perceived AM directions with a bistable motion quartet (~ 2x2 deg, 150 msec) for 1 min. We found the following results. (1) A large vertical AM adaptation display (4x4 deg, 200 msec frame duration) can bias the perceived AM direction to be more horizontal, and vice versa. This indicates AM adaptation is not location specific, which is a characteristic that is more closely associated with the attention mechanism than motion mechanism. (2) The adaptation effect was reduced when observers performed a RSVP task centrally while ignoring the more peripherally presented adapting AM display (4x4 deg). This suggests attending centrally prevents possible attention movements between tokens and thus prevents AM adaptation. (3) The adaptation effect occurred when the adapter was a continuous motion stimulus (speed: ~20 deg/sec) when presented in conjunction with the RSVP task. This indicates that AM requires attention, but continuous motion perception does not. (4) The adaptation effect occurred when the adapter was non-moving vertical or horizontal flashing bars (~ 4 deg long, duration=200 msec). This suggests that during the adaptation phase, the flashing bars were able to attract attention and to retard the stimulus-driven attention process. Taken together, these results support the hypothesis that stimulus driven attention-shift from the AM motion tokens can drive AM perception.

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26.427 **Path Shortening in Transformational Apparent Motion** Kevin C Hartstein[1](kevin.c.hartstein.gr@dartmouth.edu), Patrick Cavanagh[1, 2], Peter U Tse[1]; [1]Department of Psychological & Brain Sciences, Dartmouth College, [2]Department of Psychology, Glendon College

The length of a repeating, back-and-forth motion trajectory is underestimated by as much as 30% (Sinico et al., 2009). This effect has been attributed to path averaging within a window of about 100 ms. We tested whether path shortening also occurs for transformational apparent motion (TAM). This illusory motion occurs with the onset of a bar adjacent to a stationary square, causing the perception of a motion along the bar (Tse et al., 1998). If the bar is turned off, the bar appears to shrink back to its original form. This illusory motion allowed us to investigate whether observers perceive that the bar appears shorter when undergoing TAM. While maintaining central fixation, participants (N = 11) viewed a TAM display consisting of a square and a sudden onset and offset of an adjacent rectangle. The length of the rectangle, its location relative to the square, and its duration on screen were varied. The experiment also included real-motion control trials with incrementally growing and shrinking rectangles that resembled the reversing illusory motion perceived in the TAM display. Stimuli were either black on a gray background (first-order objects) or dynamic white noise on a static white-noise background (second-order objects). The real-motion control replicated the perceived shortening effect for both first-order and second-order bars. The effect was also observed for both first and second-order bars in the TAM display. This result indicates that a similar motion path averaging occurs for both real and illusory motion.

26.428 **Your Visual System (Probably) Knows More Physics than You Do** Colin Conwell[1](conwell@g.harvard.edu), George A Alvarez[1]; [1]Department of Psychology, Harvard University

Humans have a finely calibrated ability to navigate physical environments characterized by complex objects in complex interactions, an ability often referred to as “intuitive physics.” However, the extent to which our intuitive physics employs sophisticated computations (approximating Newtonian mechanical laws), as opposed to heuristic shortcuts, remains a matter of debate. Here we use a classic experimental paradigm to address this issue: a moving object collides with a stationary object, and observers decide which object is heavier based on the kinematics of the collision. This question can be answered perfectly using the conservation of momentum, from which one can derive the fact that the mass ratio (M1/M2) is proportional to the ratio of speed changes for each object before versus after the collision (DeltaV2/DeltaV1). Velocity-change-ratios less than 1 indicate that the first object was lighter, and ratios greater than 1 indicate that the first object was heavier. We generated displays such that the speed of only one object, or its speed change after collision, were insufficient for accurately judging which object was heavier — only by comparing the relative speed change could participants perform the task well. We find that participants could perform the task better when both objects were visible (M = .60, SEM = .02) than when the initially moving object was hidden (M = .50, SEM = .02, $t(95) = 4.94$ $p < .001$) or when the initially stationary object was hidden (M = .56, SEM = .02, $t(95) = 2.48$, $p < .05$). Thus, even though the movement of the second object alone was uninformative (performance at chance, $p = .98$), it could be usefully combined with the kinematics of the first object to make a more accurate judgment. These results suggest that our intuitive physics engine can use complex computations, like the conservation of momentum.

26.429 **Frames of Reference Determine the Direction of The Motion Aftereffect (MAE): Evidence supporting the influence of perceived motion in the MAE.** Jason P Clarke[1](clarj081@newschool.edu), Maria Kuvaldina[1], Arien Mack[1]; [1]The New School for Social Research

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The motion aftereffect (MAE) is a powerful illusion of visual motion induced by prior exposure to motion in the opposite direction. Disagreement persists on whether the key factor is retinal (e.g. Davies et al., 2011; Anstis et al., 1998; Anstis & Gregory, 1965) or perceived direction of motion (e.g. Malkinson et al., 2012: Mack et al., 1987; Mack et al., 1989). Using a novel paradigm, and taking advantage of the fact that frames of reference influence motion perception (e.g. the aperture problem), we tested the hypothesis that the MAE is affected by the perceived direction of motion of the adapting stimulus and not retinal motion. Seated in a darkened room 56 cm from the monitor, 10 participants fixated a small red cross at the center of a black screen, which was superimposed on a black and white square wave grating displacing across the retina at 3° per second and seen through one of three frames: a rectangular horizontal (subtending 2.6° x 16°), a rectangular vertical (16° x 2.6°) or a circular frame (10.6°), creating versions of the Barber Pole Illusion. The adaptation period was 30 seconds followed by testing with stationary bars viewed through a circular aperture for 5 seconds. Subjects reported the direction of any perceived motion (MAE) using a notional 'clock face' on the computer screen. Each subject received 15 blocked trials: 5 with each frame of reference. Results indicate that the MAE can be predicted by perceived motion caused by the frame of reference of the adapting stimulus, $F(2,18) = 28.99$, $p < .001$, $= .76$). These findings support the view that the critical factor in determining the direction of the MAE is perceived motion and not retinal motion.

26.430 **Motion not consciously visible can influence perception: Revisiting the Motion Bridging Effect.** Maximilian Stein[1](mstein@uni-goettingen.de), Robert Fendrich[2], Uwe Mattler[1]; [1]Georg-Elias-Müller Institute of Psychology, University of Göttingen, [2]Department of Psychological and Brain Sciences, Dartmouth College

Introduction. Rapidly rotating objects that stimulate retinal locations at high temporal frequencies (e.g., a fan blade) may appear as a stationary region (e.g., a blurred disk). Despite the inability of observers to consciously perceive the motion of such objects, information about this motion may impact perception. Mattler & Fendrich (2010) reported an instance where this occurred. Observers viewed a ring of 16 points (the inducing ring), which was rotated at angular velocities as high as 2250 deg/s so that observers saw only an unbroken outline circle. When the inducing ring was replaced by a stationary ring of 16 points this stationary ring appeared to visibly spin to a halt, primarily in the same direction as the inducing ring rotation. This illusion was labeled the Motion Bridging Effect (MBE). In the 2010 study the start and end positions of the inducing ring points and the position of the points in the stationary ring were identical. Here we investigated the effect of misaligning these positions. Methods. Displays were presented on an oscilloscope with a customized fast-phosphor CRT. The start and end positions of the points of the inducing ring were shifted relative to the fixed positions of the stationary ring by advancing those positions across the 22.5 deg angular gap that separated the successive points of the ring. Twelve steps of misalignment were investigated. Results and Conclusion. The MBE was replicated when start and end positions of inducing and stationary ring were identical. When start and end positions were misaligned, however, the MBE decreased with increasing misalignment and completely reversed when the start and end position of the points of the inducing ring were located midway between the position of the points of the stationary ring. These findings provide new constraints on the mechanisms of the MBE.

Attention: Features, objects, faces

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Poster Session, Pavilion

26.431 **Feature-based attention is constrained to attended locations in older adults** Frederik Geweke[1,2](frederik.geweke@gmail.com), Shu-Chen Li[1], Viola S Störmer[2]; [1]Department of Psychology, TU Dresden, [2]Department of Psychology, University of California, San Diego

When selecting a feature (e.g., the color red) in the visual field, target-related neural signals are enhanced globally across the visual field, operating independently of location (e.g., Martinez-Trujillo & Treue, 2004). Several studies have reported age-related declines in these effects of feature-based attention (e.g., Quigley et al., 2010). Using EEG, we here examined these age-related impairments more closely in older adults by measuring target and distractor processing within and outside the focus of attention. This allowed us to test 1) whether older adults show attentional modulations of a target relative to a distractor feature, and 2) to what extend the effects of feature-based attention spread across locations. Participants were instructed to attend to one of two overlapping colored dot arrays on one side of the visual field (left or right), and to detect brief intervals of coherent motion in the target colored dots (e.g., red) while ignoring any changes in distractors (e.g., blue; cf. Störmer & Alvarez, 2014). To measure the global properties of feature-based attention, another dot array was presented at the unattended side of the screen that either matched the target color or not. All dot arrays flickered at different frequencies, allowing the recording of distinct steady-state visual evoked potentials (SSVEPs) for each color. For the attended side, we found that visual processing was enhanced for the target relative to the distractor color ($t(15) = 3.58$; $p < 0.01$), indicating that top-down attention still effectively modulates lower-level feature representations in old age. However, SSVEP amplitudes did not show consistent effects for colors presented in the unattended visual half-field. Together these results suggest that feature-based modulations within the focus of attention are maintained in old age, but that the global properties of feature-based attention are less robust.

26.432 **Rhythmic sampling of orientation features in feature-based attention** Ce Mo[1,2,3,4](mocheck@sina.com), Bichan Wu[1], Huan Luo[1,2,3], Fang Fang[1,2,3,4,5]; [1]School of Psychological and Cognitive Sciences, Peking University, [2]Peking-Tsinghua Center for Life Sciences, Peking University, [3]IDG/McGovern Institute for Brain Research, Peking University, [4]Key Laboratory for Machine Perception (Ministry of Education), Peking University, [5]Beijing Key Laboratory of Behavior and Mental Health, Peking University

One of the most intriguing hallmarks of spatial attention is its rhythmic nature, i.e. instead of sustaining a static "spotlight" centered at the attended location, attention rhythmically samples both the attended and the unattended location at ~7 Hz. However, it remains unknown whether such a rhythmic sampling process also occurs in feature-based attention that selects and enhances the representation of visual stimuli sharing the attended feature throughout the visual field. Here, we used human behavioral data to investigate the rhythmic oscillation in feature-based attention. Subjects viewed a stimulus display consisting of two oriented (± ~45 degrees) grating arrays at random locations across the visual field for 300ms. A brief luminance increment (200ms) occurred with all gratings of one array to reset attention to their orientation. After resetting, the gratings remained on the screen for a varying cue-to-target stimulus onset asynchrony (SOA, 50-1050ms). Then they were replaced by a test display comprising of the same number of gratings of one orientation that was approximately either parallel or perpendicular to the cued orientation (50% chance, valid or invalid conditions). Subjects indicated whether the orientation in the test display was clockwise or counterclockwise of its closest orientation in the stimulus display. For both conditions, we measured orientation discrimination accuracy as a function of SOA and derived its power spectrum. We found a common ~7 Hz rhythm in the time courses in both conditions. More importantly, the accuracy time course in the valid condition exhibited a consistent anti-phase relationship with that in the invalid condition at ~7 Hz. These results suggest that the two orientation features are rhythmically sampled in alternation in feature-based attention. Our study is among the first to discover rhythmic attention sampling in feature space and speaks to a more general rhythmic temporal structure that commonly governs spatial and non-spatial attention.

26.433 **Surround Suppression in Feature-based Attention to Orientation** James A Cesaro[1,2](cesaroja@msu.edu), Wanghaoming Fang[1], Taosheng Liu[1,2]; [1]Psychology Department, Michigsn State University, [2]Neuroscience Progam, Michigan State University

Goal. Feature-based attention (FBA) enhances attended orientation at the cost of unattended ones. However, the precise attentional modulation profile still remains unclear. While the feature-similarity gain model predicts a monotonic modulation profile, the surround suppression model suggests a non-monotonic (Mexican hat) profile. Here, we systematically investigated how attending to an orientation modulates the perception of unattended ones. Methods. Stimuli consisted of 180 oriented bars, which were randomly located within an annulus centered on the fixation. In a two-interval forced choice task, participants reported the target-present interval. Targets were defined as the stimulus in which a proportion of bars shared the same orientation, while noise stimuli contained bars with all different orientations. The proportion of consistently oriented bars in the target (coherence) was first determined individually via an adaptive staircase. Then, in a feature cueing procedure an orientation precue was presented before the stimuli, indicating the coherent target orientation in 60% of trials. In the remaining trials, the target could be ±15°, ±30°, ±45°, ±60°, ±75°, or 90° offset from the cued orientation. We also included a neutral condition (no precue) as a baseline to assess attentional modulation. Results. Compared to the neutral baseline, we found a significant enhancement for valid trials (0°) and a significant suppression effect when cue and target are orthogonal (90°). Importantly, there were also suppressions at ±45° followed by rebounds at ±60°. Model comparison strongly favored a non-monotonic (Mexican hat) profile over a monotonic (Gaussian) profile. Conclusion. Attention to orientation elicits a non-monotonic modulation, suggesting a combination of surround suppression and feature similarity gain at different scales.

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26.434 **Active Attentional Suppression Cannot Be Explained by Recoding to a Positive Template** Nancy B Carlisle[1](nancy.carlisle@gmail.com); [1]Department of Psychology, Lehigh University

Traditional attentional theories suggest that attentional control is instantiated by enhancing the processing of known target features. But can we also suppress known distractor features? Arita, Carlisle, & Woodman (JEP:HPP, 2012) reported cuing a distractor color (negative cue) led to faster RTs compared with neutral cue trials. In this design, search arrays contained two colors of objects, where all objects of one color appeared in one hemifield. An alternative explanation for these results is that participants waited until the search array was presented and created a positive template after seeing the array (Becker, Hemsteger, Peltier, VisCog, 2015). Becker and colleagues found that presenting multiple colors in the search array eliminated the benefit of the negative cue. This manipulation may have reduced the participant's perceived benefit of the negative cue, meaning that this failure to replicate may be due to differential strategies adopted by participants. To address this potential strategic difference between the two studies, I created a design with 1/3 of trials in a block with multi-color arrays (as in Becker and colleagues, 2015), and 2/3 of trials with two-color arrays (as in Arita and colleagues, 2012). Importantly, participants did not know which array arrangement would appear, and therefore needed to adopt a strategy based on the utility of the cue for the entire block. I found a main effect of cue type on reaction time, with both positive and negative cues leading to significant benefits. However, there was no interaction between cue type and array color type, in contrast to the shift-to-positive template hypothesis. This suggests we can use top-down control to suppress, but may only utilize controlled suppression when it is strategically advantageous.

26.435 **Templates for rejection occur only in early trials in intermixed search arrays** Tomoyuki Tanda[1](t-tmyk-04-26@eis.hokudai.ac.jp), Jun Kawahara[1]; [1]Department of Psychology, Hokkaido University

Our visual system can actively prioritize a specific property to search for a target. Similarly, the system can suppress a group of distractors containing an irrelevant property, enhancing search performance. Such suppression, known as templates for rejection (Arita, Carlisle, & Woodman, 2012), has been demonstrated when search arrays of colored items were segregated according to hemifield; however, no suppression was found when the items were spatially intermixed. The present study examined the effect of spatial arrangements (i.e., spatial segregation or intermixing) on the efficacy of templates for rejection when items are differentiated by shape. Participants indicated the orientation of a target line segment in a shape when items were spatially segregated according to hemifield. They were precued by (a) a positive cue (e.g., a circle), indicating that the target will appear in the cued shape; (b) a negative cue (e.g., a square), indicating that the target will never appear in the cued shape; or (c) a neutral cue, indicating that the shape will not appear in the present search array. Reaction times for orientation judgments were faster under the negative- than under the neutral-cue condition, suggesting the operation of templates for rejection based on shape. As subsidiary experiments used intermixed search arrays, no templates for rejection were expected based on the literature. Although, the results showed no templates for rejection when averaged across whole trials, closer inspection of the data revealed that templates for rejection were created, but only in the earliest block. We also found that reaction times showed the largest decrease under the neutral-cue condition when compared to the negative-cue condition. We conclude that shape-based templates for rejection can be created when items are spatially segregated. Templates for rejection are available even in spatially intermixed arrays, although the suppression effect dissipates quickly in the course of trials.

26.436 **Examining the limits of feature integration** Greg H Huffman[1](greg.huffman@mail.utoronto.ca), Mathew D Hilchey[2], Jay Pratt[3]; [1]University of Toronto, [2]University of Toronto, [3]University of Toronto

Feature integration effects are prevalent in many visual cognition tasks that require stimulus identification. In many cases, these feature integration effects are "nuisance" effects in that they obscure the effects under study, possibly leading to invalid inferences. Eliminating these effects has proven difficult. Here, we manipulated a paradigm in which feature integration effects have been shown to be surprisingly absent in order to learn about the limits of such effects limits. In the prime-search paradigm, individuals sometimes make a response to a centrally presented prime stimulus (a colored circle). This is followed by a visual search where the target stimulus may or may not appear in a placeholder matching the prime stimulus. Typically, response are faster when the target's placeholder matches the prime than when it does not, but only when individuals respond to the prime. Across four experiments we gradually increased the overlap in stimulus location and response demands between the two tasks to determine what is necessary to cause feature integration effects to appear. We found that stimulus location overlap alone was insufficient to generate feature integration effects. Similarly insufficient was having location overlap and response overlap (i.e., both responses with the spacebar). With stimulus location overlap and a lateralized response set, however, feature integration effects appeared. This remained the case when we removed the distractor item from the second task. Interestingly, the feature integration effects were consistent with those predicted when a task switch occurs, rather than those found more commonly. This study indicates that the lack of integration effects in the prime-search task result from participants representing the two parts as separate tasks along with the lack of stimulus location and response set overlap. Furthermore, the data has implications for understanding the limits of feature integration and the interplay between task switching and feature integration.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

26.437 **Attentional deployment to Space and Features: Separate and Together** Guangsheng Liang[1](guangsheng.liang@ttu.edu), Miranda Scolari[1]; [1]Department of Psychological Sciences, Texas Tech University

Top-down visual attention selectively filters sensory input so relevant information receives preferential processing. Feature-based attention (FBA) enhances the representation of attended low-level features, while space-based attention (SBA) enhances information at attended location(s). Both selection mechanisms operate upon common neuronal populations within visual cortex, but how their unique influences combine to facilitate behavior remains a focus point of study. Here, we utilized an arrow precue containing color and spatial information that together predicted a relevant object (unfilled square) 70% of the time (fully valid condition). For the remaining 30% of trials, the relevant square either: occupied the cued location but was depicted in an uncued color (space-valid, feature-invalid; 10%), was in the cued color but an uncued location (feature-valid, space-invalid; 10%), or mismatched the cued location and cued color (fully invalid; 10%). Importantly, the subjects' task— to report the location of a gap on the square—was completely orthogonal to all precued information. Thus, we could investigate whether FBA and SBA are deployed independently or jointly in a discrimination task that does not favor one mechanism over the other. Additionally, we employed a variable target onset time of 500, 1000 or 1500 ms to coarsely explore any temporal differ-

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ences and/or interplays between mechanisms. Notably, discrimination performance should be maximized if FBA and SBA are simultaneously and independently deployed. Instead, at 500 ms, FBA and SBA were deployed conjointly: Enhancement of the cued feature was restricted to the cued location. By 1500 ms, subjects relied only on the spatial cue. In another study, where subjects viewed only a feature or spatial cue, FBA deployment was similarly early and transient, while SBA was deployed later and sustained longer. The temporal differences between mechanisms when tested separately suggest independence, while the combinatorial deployment indicates limits to this independence, likely due to a common resource.

26.439 **Attentional spread during one-shot visual perception of multiple objects** Alexey U. Yakovlev[1](bonashee@gmail.com), Igor S. Utochkin[1]; [1]National Research University Higher School of Economics, Russia

The capacity of fine vision of individual object is limited by the "bottleneck" of attention and working memory. Still, at every moment we see large collections of objects. What exactly happens to individual representations when the observer attempts to distribute attention between multiple objects? One view is that a fixed number of objects are represented with good fidelity while others are represented with poor fidelity. Another theory is that attention is evenly distributed among all objects but fidelity decreases as set size grows. This debate is one in the core of a theory of summary representation of multiple objects (Alvarez, 2011; Myczek & Simons, 2008). Here we directly tested how the capacity and fidelity change with set size. Participants were briefly shown sets of 1, 2, 4, or 8 circles of various sizes. Then, one of the circles increased or decreased in size by 2- 20% (change step 2%). The change was synchronized with a global background flash masking the local transient caused by the circle change. Observers had to respond whether they had seen an increment or decrement in any of the circles (2AFC). These manipulations rely on an assumption that one needs attention to the stimulus to spot a change (Rensink et al., 1997). Psychometric functions were fit using normal cumulative density functions. We found that the set size affects the probability of correct response at which the function reaches a plateau: the larger was a set size, the lower was such probability. The standard deviations of the functions typically associated with fidelity were relatively similar across set sizes within each observer. We conclude, therefore, that, when observers perceive multiple objects during a short time, they focus attention on a limited sample of items represented with the same fidelity, rather than evenly distribute it among all the objects.

26.440 **A CNN Model of "Objectness" Predicts Fixations During Free Viewing** Yupei Chen[1](yupei.chen@stonybrook.edu), Gregory J. Zelinsky[1,2]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

Although object representations are known to guide attention during goal-directed behaviors, their importance in free scene viewing, a task often assumed to be minimally goal-directed, is debated and where bottom-up saliency-based models are still dominant. Here we introduce a top-down object-based model of fixation prediction during scene viewing. Our premise is that the same visual object representations learned and used to control goal-directed behavior are also used to guide attention to objects even during free viewing. What distinguishes our model from other object-based models of attention is that it is image-computable, meaning that it needs no hand labeling of a scene's objects. An image is input to a state-of-the-art CNN pre-trained for object classification using 1000 object categories from ImageNet. An activity visualization method (Grad-CAM, Selvaraju et al., 2016) is then used to localize regions of activation in this image corresponding to each of the 1000 categories for which the CNN was trained, thereby creating 1000 object-category-specific priority maps. Summing and normalizing these maps produces a single priority map reflecting the general "objectness" of locations in an image. Doing this for images from the MIT-ICCV dataset and comparing that dataset's gaze fixation ground truth to the model predictions, we found that the mean AUC score for our model was as good or better than those for comparable saliency models. By showing that an image-computable, object-based model can predict fixations during scene viewing, a viable alternative now exists to bottom-up saliency models, as well as a computational method for quantitatively distinguishing attention guidance to the objects in a scene versus attention to lower-level feature contrast. Lastly, because our model of free viewing is essentially a simultaneous hybrid search for 1000 target-object categories, the tasks of free viewing and visual search are finally unified under a single theoretical framework.

26.441 **Distinct neural sources of expectations about features and objects** Peter Kok[1](peter.kok@yale.edu), Lindsay Rait[1], Nicholas B. Turk-Browne[1]; [1]Department of Psychology, Yale University, New Haven, CT, USA

Sensory processing is strongly influenced by our prior knowledge. In line with this, expectations about both simple features (e.g., orientation) and complex objects (e.g., abstract shapes) modulate processing in visual cortex. However, it is unclear whether or not these two types of expectations operate via the same underlying mechanism. For example, expectations about features may result from computations within visual cortex and induce global modulation, whereas expectations about objects may require feedback from higher-order, domain-general memory systems like the hippocampus. To address this question, we compare the influence of predictions about the orientation of grating stimuli to the influence of predictions about abstract shapes (i.e., Fourier descriptors). Using high-resolution fMRI in conjunction with inverted encoding models, we found that the neural representation of both gratings and shapes was delayed when they were incorrectly predicted. However, the effect for shapes was present throughout the visual cortical hierarchy (V1, V2, and LO), whereas for gratings it was limited to V1. Moreover, when oriented gratings were expected but omitted, the pattern of activity in V1 (but not higher-order visual cortex) reflected the expected orientation, suggesting that such expectations can evoke a template of the expected feature in sensory cortex. In contrast, this did not occur for expected (but omitted) shapes, suggesting that top-down shape expectations and bottom-up shape stimuli are represented via different neural codes. Finally, we found that the hippocampus represented expected shapes, but not expected gratings. In fact, the hippocampus signaled unexpected orientations, more consistent with coding of prediction errors. Altogether, our findings suggest that expectations about low-level features and higher-level objects may involve distinct neural mechanisms.

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26.442 **Automatic Encoding of Visual Numerosity** Nicholas K DeWind[1](ndewind@gmail.com), Marty Woldorff[2], Elizabeth M Brannon[1]; [1]Psychology, University of Pennsylvania, [2]Psychology and Neuroscience, Duke University

The ability to approximately enumerate without counting emerges early in human development and is shared with non-human animals. Single-neuron recordings in monkeys and functional magnetic resonance imaging (fMRI) in humans have demonstrated that the intraparietal sulcus (IPS) and superior parietal lobule (SPL) are involved in representing the number of items in a display. Some of these experiments have required estimation or comparison of number, while others have only required participants to maintain attention without engaging in an explicit numerical task. There have also been reports of number encoding in early visual cortex (EVC), without a numerical task. Here we used an event-related fMRI design to test the role of explicit number comparison in shaping the cortical representations of number in parietal and early visual regions. Ten participants viewed arrays of dots that varied in both number and color. On half the trials in a run, participants made a decision about the color of the items and on the other half about their number. Participants also performed a localizer task to identify the parietal regions associated with numerical cognition. We used a support vector machine (SVM) to decode stimulus number from voxel-level signal intensity. The SVM was applied to the parietal ROI defined by our subject-specific localizer, as well as by atlas-defined ROIs estimating the location of retinotopic maps in V1, V2, V3, and IPS/SPL. The results showed that we could decode number in all 5 ROIs during both the number and color discrimination tasks. We found that there was no significant effect of task (number vs. color) on this decoding in any ROI. These findings indicate that number is encoded automatically in both early visual and parietal areas when people attend to an array, regardless of the feature they are discriminating.

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Saturday PM

26.443 **Ensemble information is built with a bag of free-floating visual features.** Oakyoon Cha[1](oakyoon@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Researchers have suggested that responses to multiple visual stimuli can be transformed into a single population response, which serves as a representation that enables people to quickly extract ensemble information from multiple visual elements (e.g., average orientation of tilted bars). This population response account assumes that the visual system disregards location information from multiple visual features and aggregates them as the same population response. The current study explored this concept of a representation built with a bag of free-floating visual features. We created visual stimuli by applying the Fourier transform to either a Gabor patch or a natural image, and then adding noise to either spectral power or phase distributions, independently. Participants were tested with two different tasks, which were associated with different types of stimuli and noise. First, participants judged the average orientation of multiple Gabor patches with random noise added to the spectral power/phase distributions. We found that noise added to the locations of sine-wave components (i.e., random phase noise) did not have much influence on the average orientation judgment. Second, participants categorized natural images with noise added, but this time, noise was derived from other natural images, and thus made systematic biases in the spectral power/phase distributions. If an ensemble comprises free-floating visual features, participants would not be able to filter systematic biases in the location information, and that would disrupt categorization performance. As expected, participants were not good at categorizing natural images with phase noise derived from other, irrelevant natural images. We suggest that an ensemble representation is built from a bag of visual features, and their location information is not bound to each visual feature. Thus, an ensemble is resistant to unbiased random phase noise, yet prone to systematic biases in the spectral phase distribution.

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26.444 **Object-based attention is modulated by shift direction and visual field quadrant** Adam J Barnas[1](ajbarnas@uwm.edu), Adam S Greenberg[1]; [1]Department of Psychology, University of Wisconsin-Milwaukee

Visually attended objects are afforded an enhancement of information relative to unattended objects, known as object-based attention (OBA). We recently demonstrated that shifts of OBA are anisotropic (what we call a Shift Direction Anisotropy, SDA), suggesting they are more efficient along the horizontal meridian compared to the vertical meridian (Barnas & Greenberg, 2016). Our goal here was to determine whether the SDA is driven by a specific shift direction (i.e., left-to-right or top-to-bottom) beyond a general horizontal shift advantage, and whether the SDA varies with visual field quadrant. Participants were presented with an L-shaped object, composed of a horizontal rectangle fused with a vertical rectangle. Following a partially valid peripheral cue, participants detected a target that appeared at the cued location ('valid') or at one of two equidistant, noncued locations at either the horizontal ('invalid-horizontal') or vertical ('invalid-vertical') object end. Results revealed no significant RT difference along the horizontal meridian when reallocating OBA left-to-right vs. right-to-left. However, there was a significant difference along the vertical meridian – RTs were significantly faster when reallocating OBA bottom-to-top vs. top-to-bottom. Additionally, horizontal shift advantages (invalid-horizontal RT < invalid-vertical RT) emerged in upper visual field quadrants, whereas vertical shift advantages (invalid-vertical RT < invalid-horizontal RT) emerged in lower visual field quadrants. These results suggest that the SDA emerges due to a specific impairment when shifting from top-to-bottom, as well as a general horizontal shift advantage, and is modulated by visual field quadrant. Together, these findings provide provisional support for a neurobiological explanation of the SDA based on the representation of the visual fields in retinotopically-mapped visual cortex.

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26.445 **Object-based warping: Exploring links to attention** Kerri A. Walter[1](kwalter@udel.edu), Gregory Wade[1], Timothy J. Vickery[1]; [1]University of Delaware

Two dots bound together by placement on an object's surface appear further apart than the same two dots not surrounded by an object, suggesting that space within objects is perceptually expanded ("object-based warping," Vickery & Chun, 2010, Psychological Science). One possible cause for this illusion is attention, which may concentrate within the boundaries of an object and distort spatial perception. We explored potential links between attention and object-based warping by manipulating the attentional requirements of a spatial adjustment task. Subjects (N=20) viewed displays consisting of "reference" dots on one side of the screen, and "adjustment" dots on the other. They manipulated adjustment dot spacing to match the spacing of the reference dots. The reference dots were either surrounded by a closed rectangular contour ("object") or not. In addition, we manipulated the contrast of the dots: reference and adjustment dots were presented in high- or low-contrast (black or gray, on a light-gray background), creating four contrast conditions (high-reference/high-adjust, low-reference/high-adjust, etc.). We reasoned that low-contrast dots would require a higher concentration of attention during this task. Replicating prior work, assessments of dot spacing was influenced by the presence of the object; within all four contrast conditions, subjects reported that object-surrounded dots were spaced further apart than equivalent non-object displays (all $p < .001$). Overall, non-object dots were reported as 2.9% further apart than reality , compared with 6.1% for object-surrounded dots. Critically, contrast also affected distortions. In non-object conditions, when reference dots were low-contrast and adjustment dots were high-contrast, distortions were greater (5.3%) compared to when both sets of dots were high-contrast (3.3%) or both were low-contrast (2.1%; both $p < .001$). These results demonstrate that attention can drive similar space-distorting effects as the presence of an object, and support the possibility that object-based warping may be due to effects of object presence on attention.

Acknowledgement: NSF OIA 1632849 NSF BCS 1558535

26.446 **The Influence of Shape Curvature on Decision-Making Processes** Grace E Remboldt[1](grace.remboldt@gmail.com), Rebecca J Neal[1], Olivia R Krieger[1], Alexandra Theodorou[1], Jesse J Bengson[1]; [1]Department of Psychology, Sonoma State University

Previous studies on object preference have demonstrated preference for curvature over angularity. Evidence suggests something fundamental about curvature that generates attraction and positive response. Although positive valence associations have been demonstrated, no study has explored the role of curved contour on decision-making. We designed an experiment in which participants were presented with a cue and instructed to make a decision to expect something happy or something sad. Each cue presented was either curved or its angular counterpart. We found an effect of curvature, demonstrating that participants were more likely to expect something happy when presented with curved stimuli. These results provide evidence that curvature in the visual field may bias decisional outcomes.

Acknowledgement: Koret Foundation

26.447 **Visual Processing of Spatial Relations Within and Between Objects** Christine E. Nothelfer[1](cnothelfer@gmail.com), Steven Franconeri[1]; [1]Department of Psychology, Northwestern University

Spatial relation perception (e.g., finding a plus above a dash, among dashes above pluses) is an inefficient process (Logan, 1994; Wolfe, 1998; Franconeri et al., 2012), but dramatically improves when the target is a single object, such as a short rectangle and tall rectangle with 0 degrees of spacing between them, compared to 1 degree between them (Nothelfer & Franconeri, VSS 2017). However, it is unclear whether this improvement stems from the target simply being a single object, or because the target's components are closer together and subsequently grouped more easily by proximity. An object-based hypothesis of spatial relation processing predicts that 0-degree spacing is a special case, such that finding this target relation among 0-degree distractors is easier than finding a non-0-degree target among non-0-degree distractors, independently of the actual degree of spacing. The purely space-based (i.e., object-blind) view predicts that search efficiency declines linearly as inter-object

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spacing increases from 0. Participants were asked to find a particular relation among the opposite arrangement (e.g., small/large rectangle among large/small rectangles). The rectangles (0.63 degrees in width) were separated by a space 0, 0.06, 0.19, or 0.57 degrees in width. Displays were divided into quadrants each containing 1-5 rectangle pairs with always the same degree of spacing within a trial, for a total set size of 4-20 rectangle pairs. Participants were asked to quickly indicate which quadrant contained the target relation. Visual search was more efficient when participants searched for two adjacent rectangles (0 degrees separated), rather than two separated rectangles (0.06, 0.19, or 0.57 degrees separated). Critically, additional space between the rectangles did not further degrade search, supporting an object-based view. These results show that visual processing of spatial relations is substantially better when judging a single object, and this is not simply due to closer proximity of its components.

26.448 **Weak interactions between surface and shape featured-based forms of attention during object perception** Nina Lee[1](ninah.lee@mail.utoronto.ca), Matthias Niemeier[1,2]; [1]University of Toronto Scarborough, [2]Centre for Vision Research, York University

Feature-based attention is well known to facilitate detection of stimuli or transients. Further, attention to features is known to aid in object perception; in particular, features that provide information about the surface properties of objects such as colour, and features that offer cues about the shape of the object. However, the influence of colour and shapes has never been tested together. The aim of the current study was to therefore test for interactions. To this end, participants detected the incomplete outlines of objects embedded in random arrays of lines and indicated their spatial location (left or right of centre). Attentional colour cues were conveyed through the frame and fixation point that predicted the colour of the upcoming object with 70% probability, and shape expectations were manipulated by sorting trials into blocks which repeated a single shape, or blocks which randomly displayed one of eight shapes each trial. As expected, we found colour cues and shape knowledge both to increase object perception accuracy. Surprisingly however, we observed no interaction between cues in that both together produced no super-additive benefit of attentional cueing. Our results suggest that object perception incorporates surface and shape feature cues through largely independent mechanisms. These results shed new light on the top-down processes of visual object recognition.

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26.449 **Task-Irrelevant Semantic Relationships Between Objects and Scene Guide Visual Attention** Joseph C Nah[1](nah@gwu.edu), Sarah Shomstein[1]; [1]The George Washington University

While the influence of task-relevant semantic relatedness on attentional allocation has been well established, recent behavioral evidence emerged suggesting that the influence of semantic information is not constrained by task-relevance (Malcolm, Rattinger, & Shomstein, 2016). Additionally, our most recent work provided evidence that task-irrelevant semantic relationships between objects modulate spatial attention and enhances neural representation of objects in early visual cortex. These results provide evidence that high-level semantic relationships among objects continuously guide attentional selection. However, objects rarely, if ever, appear in the absence of a scene. Thus, it is imperative to understand how the object-object semantic relationship interacts with object-scene semantic relationship to influence attentional selection. Here, we investigated the degree to which semantic relationship between objects and scenes interact to guide attentional allocation. In the first experiment, participants were presented with a scene followed by two objects appearing on either side of fixation after a brief delay. Only one of the objects was semantically related to the scene. Two Gabor wavelets then appeared, one on fixation and one on top of an object, and a checkerboard distractor on the other object. Participants reported whether the two Gabor wavelets' orientation matched. Critically, the peripheral target was equally likely to appear on either object, rendering semantic relationships task-irrelevant. Faster RT were observed for peripheral targets that appeared on the semantically related object. Importantly, RTs were directly related to the strength of scene-object relatedness (assessed by a questionnaire). In the second experiment, participants were presented with three objects, with two objects semantically related to each other and the other semantically related to the scene. Combined, the results suggest that semantic relationships between scenes and objects interact to continuously influence attentional selection, and that this influence is modulated by the strength of semantic relationships.

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26.450 **Controling for Perceptual Differences in the Faces Flanker Task** Regard M Booy[1](regardbooy@gmail.com), Thomas Spalek[1]; [1]Psychology, Simon Fraser University

It has been suggested that negative stimuli capture attention more readily, and hold attention for longer than positive or neutral stimuli. Results consistent with this interpretation have, been found using a modified version of the Eriksen flanker task using schematic representations of emotional faces as the stimuli. Specifically, reaction times to happy faces are delayed when sad faces are presented as flankers (incongruent condition) relative to when happy faces are used as flankers (congruent condition). But this incongruent/congruent difference is not observed when the target is a sad face. It has been suggested that this effect may not be due to the valence of the stimuli and instead represent the ease of feature processing. For example, the mouth may be easier to process in a happy face than in a sad face because the contours of the lower part of the face and a happy mouth are roughly parallel. To test this hypothesis, 88 undergraduate students completed a Flanker task using schematic faces without the encompassing circle (i.e., just the eyes and mouth) as stimuli. A central target with three flankers on either side were presented in a horizontal line in the centre of the screen. As expected, a congruency effect was observed for happy faces. However, contrary to previous findings, a congruency effect was also observed for sad faces. If previous results were due to low level perceptual difference between schematic faces alone, no differences should be observed between happy and sad targets in the present study. Instead, the congruency effect was larger for happy than for sad faces. This is consistent with research suggesting negative stimuli capture attention more readily than positive stimuli, and further suggests that emotional information conveyed by the stimulus impacted responses.

Acknowledgement: NSERC

26.451 **Task-Dependent Information Compression in Face, Object and Scene Categorization** Katarzyna Jaworska[1](katarzyna.jaworska@glasgow.ac.uk), Oliver GB Garrod[1], Nicola J van Rijsbergen[1], Arjen Alink[2], Ian Charest[3], Philippe G Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, Glasgow, UK, [2]Department of Systems Neuroscience, University Medical Centre Hamburg-Eppendorf, Hamburg, Germany, [3]School of Psychology, University of Birmingham, Birmingham, UK

Every day, we encounter multiple visual scenes, which contain vast amounts of information that must be selectively attended or inhibited to avoid sensory overload. Here, we sought to understand the selective information contents that underlie successful categorization of faces, objects and scenes within the same images. This approach confers the advantage of isolating the effects to the active observer resolving a categorization task because the input to the visual system is constant across tasks. Five observers each performed five categorization tasks across 4,482 trials (facial expression, identity, general scene, specific scene, and object) on the same set of complex naturalistic selfie images. We decomposed each selfie image with Gabor features at 6 orientations, 7 spatial scales, and 3,108 spatial locations. We kept the top 35% of the Gabor features as specified by power ranking range averaged across all selfies. Then, we randomly sampled 5% of the Gabor features (i.e. ~2,400 Gabor features) to produce a sparse stimulus shown on an individual trial (see Supplementary Figures). Following the experiment, independently for each observer we used binary linear regressions to reverse correlate the single trial relationship between random sampling of Gabor coefficients and the face, object or scene categorization responses in the task. We demonstrate selective task-dependent information compression. On average, observers used 10.38% of available Gabor features for categorizing expressions, 16.94% for identity, 39.62% for objects, 90.22% for general scenes, and 94.56% for specific scenes. Task-dependent information compression reveals the specific face, object and scene features that the brain must differentially represent from the same images to achieve successful categorization behavior. Therefore, as categorization tasks change the information content that the brain must process, they should play a prominent role in explanations of information processing mechanisms in brain and artificial networks.

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Temporal Processing: Timing, duration, latency

Saturday, May 19, 2:45 - 6:45 pm

Poster Session, Pavilion

26.452 **The perception and meta-perception of time within and between modalities** Simon J Cropper[1](scropper@unimelb.edu.au), Amy Kendrick[1], Patrick Goodbourn[1], Aurelio Bruno[2], Alan Johnston[3]; [1]School of Psychological Sciences, University of Melbourne, Victoria, Australia, 3010, [2]Department of Experimental Psychology, University College London, UK, [3]School of Psychology, University of Nottingham, UK.

We are interested in how we perceive time and how we accumulate and use our internal representation of a temporal interval. The work described here examines the perception of short durations of time in visual and auditory stimuli and the subjects' knowledge of their performance over repeated trials. Subjects were presented with 2 intervals containing a stimulus of the same duration (1500ms or 3000ms). The stimuli were visual gratings or auditory tones or a combination of the two. Subjects initiated presentation of each interval with a button-press and released the button when they considered the stimulus to be half-way through; they then indicated their 'best estimate' of the pair. Each subject (n=6) performed 500 trails in the same order as each other for 8 different conditions. Data was analysed in terms of first/second interval; 'best'/'worst' Actual Observer estimate; 'best'/'worst' Ideal Observer estimate. From this we were able to judge both the subject's performance on the task and their insight into their own decisional 'noise' in an Ideal observer framework. Visual and audio-only conditions showed similar mean bisection-points and (moderate) order-effects but with significantly less variance for the audio judgment. Mixed-modality conditions indicated no systematic change in bisection-point but an overall reduction in variance. There was no evidence for a scalar effect of duration in any condition and metacognition of performance was consistently good across conditions. The presentation regime allowed examination of the accumulation of the internal representation of the interval and its effect on future performance which suggests subjects use the last 4 estimates in their current judgment. The data suggest that subjects integrate effectively across modalities to generate an internal estimate of time close to, but subjectively different from, the actual time to be judged. This interval is learned rapidly but constantly updated throughout the observation period.

26.453 **The temporal profile of visual encoding.** Martin Arguin[1](martin.arguin@umontreal.ca); [1]Centre de Recherche en Neuropsychologie et Cognition and Département de psychologie, Université de Montréal, Montréal, Canada.

The progression of visual encoding effectiveness through time was determined in a visual word recognition task using 200 ms stimuli (5-letter words) with randomly oscillating signal-to-noise ratio (SNR; ranging between 0 and .5; noise component made of white noise). SNR's were generated by combining 5-60 Hz sinewaves (5 Hz steps) of random amplitudes and phases. Stimuli were displayed at a temporal frequency of 120Hz and stimulus energy was equated across image frames. Individual (n = 8) classification images of encoding effectiveness through time were constructed by the weighted subtraction of SNRs leading to errors (average accuracy of 61%) from those associated with correct target identification. They were transformed into Z scores by bootstrapping (1000 iterations) and then averaged across participants. A similar procedure was applied on time-frequency analyses of the SNRs for each trial to obtain a classification image of encoding effectiveness in the time-frequency domain. The temporal classification image showed that visual encoding effectiveness was just above the significance threshold ($p < .05$; Pixel test; Chauvin et al., JOV 2005) on the first target image frame (8 ms). It then rose steeply up to 50 ms after target onset, to then decline gradually in an oscillating wave with progressively diminishing peaks at 83, 117, and 167 ms. After 183 ms following target onset, encoding effectiveness was no longer significant. The time-frequency classification image showed relatively wide bandwidth (ranging from 20 to 40 Hz in width) significant activity between 0 and 114 ms after target onset with peaks ranging between 15 and 30 Hz. Another significant 55 Hz peak occurred at 144-171 ms SOA. Visual encoding effectiveness is temporally discontinuous and appears to involve at least two oscillating mechanisms, an early one roughly in the range of 15-30 Hz and late one at about 55 Hz.

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26.454 **The nature of the impairment brought about by temporal crowding** Yaffa Yeshurun[1](yeshurun@research.haifa.ac.il), Shira Tkacz-Domb[1]; [1]Psychology department, University of Haifa

Recently we demonstrated that crowding also occurs in the time domain: target identification is impaired when other items appear before and/or after the target, at the same location. Such temporal crowding emerged even when the SOA between the target and the preceding and succeeding stimuli was longer than 400 ms. These long-lasting temporal effects did not depend on temporal or spatial uncertainty, but they were reduced when target location was attended. Interestingly, we did not find an interaction between spatial and temporal crowding. In the current study we employed a continuous measure of perceived orientation to examine the nature of the impairment brought about by temporal crowding. A single trial included a sequence of three randomly oriented stimuli presented at 9^o of eccentricity. The target was always the second stimulus. SOAs varied between 175 to 475 ms. The stimuli sequence was followed by a probe, and the participants had to rotate it to reproduce the target's orientation. The measure of performance was the angular difference between the target's original and reported orientation. A mixture-model analysis revealed significant effects of SOA on the observers' orientation report precision and on the rate of reporting the orientation of a non-target item, but there was no significant SOA effect on guessing rate. These findings suggest that temporal crowding, like spatial crowding, impairs the precision of encoding processes and increases substitution rate, but does not affect signal-to-noise ratio. This pattern of results is different from that found previously with classical forward and backward masking – classical masking affected mainly signal-to-noise ratio and precision, but did not affect the rate of reporting a non-target orientation. These different patterns of results suggest that temporal crowding is not merely 'particularly long' masking effects, but rather involves different processes.

26.455 **Domain specific interactions between expectation and priming for sensory modality and timing** 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

Both the sensory modality and the timing of relevant events often vary predictably in natural environments, so that it is beneficial to adapt the sensory system to such variations. Indeed, statistical information about target sensory modality and/or timing facilitates behavioral responses—called expectation effects. Responses are also facilitated by short-term repetitions of target sensory modality and/or timing—called priming effects. We examined how expectation and priming effects interacted when expectations about target modality (auditory vs. visual) and timing (short vs. long cue-to-target interval) were concurrently manipulated. Target-modality expectation (80% auditory with 20% visual target, or vice versa) was manipulated across participants, while target-timing expectation (80% short with 20% long cue-to-target interval, or vice versa) was manipulated across blocks. Target-modality and target-timing expectations speeded response times (faster responses when targets were presented in the expected modality and/or at the expected timing) in an additive manner, suggesting that they operate relatively independently. Responses were also faster when the modality and/or timing of targets were repeated across trials—priming effects. Importantly, the interactions between expectation and priming were domain specific. For directing attention to target modality, modality-priming effects predominated for auditory targets whereas modality-expectation effects predominated for

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visual targets. For directing attention to target timing, temporal-expectation effects were observed only when temporal-priming effects were absent (i.e., when the timing changed relative to the preceding trial). Crucially, modality priming did not interact with temporal expectation, and temporal priming did not interact with modality expectation. Thus, the interactions between "global" statistical and "local" priming processes appear to be controlled separately within the mechanisms that direct attention to specific sensory modalities and within the mechanisms that direct attention to specific temporal intervals. These results may suggest that the sensory system concurrently optimizes attentional priorities within sensory modality and timing domains.

26.456 **Double Dissociation in Radial & Rotational Motion-Defined Temporal Order Judgments** Leslie Welch[1](Leslie_Welch@brown.edu), Nestor Matthews[2], Elena Festa[1], Kendra Schafer[2]; [1]Cognitive, Linguistic & Psychological Sciences, Brown University, [2]Department of Psychology, Denison University

Introduction: Rotational and radial motion register in the Medial Superior Temporal (MST) region of the primate visual system, according to prior neurophysiological research (Smith et al., 2006; Strong et al., 2017). Here we psychophysically probed the independence between these two MST-mediated motion types. Method: We bilaterally presented plaids that either radiated or rotated before changing direction. College students reported whether the direction changed first on the left or right –a temporal order judgment (TOJ). In Exp 1 (n=31; 17,360 trials), the two plaids either initially moved in the same or opposite direction. In Exp 2 (n=30; 16,800 trials), all plaids initially moved in the same direction and contained either no phase noise (as in Exp 1), or phase noise from a 0-to-45 degree phase range. To promote reproducibility, the Open Science Framework (https://osf.io/knvxj/) contains the complete data set and all software necessary for replicating the study. Results: Exps 1 & 2 each generated statistically significant 2x2 interactions, but with distinct patterns. In Exp 1, changing from same to opposite initial directions impaired TOJs on radially defined asynchronies but improved TOJs on rotationally defined asynchronies ($F(1,30) = 67.324$, $p < 0.001$, partial eta^2=0.692). Dissimilarly, in Exp 2 adding phase noise impaired TOJs significantly more on rotationally than on radially defined asynchronies ($F(1,29) = 6.213$, $p = 0.019$, partial eta^2=0.176). Specifically, Exp 1's direction manipulation increased radial TOJ thresholds 225% (from 88 to 286 ms), but decreased rotational TOJ thresholds 30% (from 87 to 61 ms). By contrast, Exp 2's phase manipulation increased radial TOJ thresholds 30% (from 69 to 90 ms), and increased rotational TOJ thresholds 70% (from 86 to 146 ms). Conclusion: The findings suggest a double dissociation between the neural events that track the temporal order of asynchronies defined by two types of MST-mediated motion.

26.457 **Saccadic eye movement following a moving object results in a longer perceived duration compared with smooth pursuit** Riko Iizuka[1], Yuko Yotsumoto[1]; [1]the Department of Life Sciences, the University of Tokyo

Saccadic eye movement affects perception of time. When a stimulus appears during a saccade, the perceived duration of that stimulus is compressed. However, these results were obtained using a static target, and the saccades were made to follow different stimuli appearing at different locations. It remains unknown whether eye movements following a moving target changes the perceived duration of that target. A moving object itself has been reported to induce time dilation. Therefore, following a moving target induces a conflicting situation: the stimulus motion may induce time dilation while saccade may induce compression. We examined whether time perception of a target stimulus is affected by saccadic eye movement following the target stimulus itself. We hypothesized that a stimulus followed by saccade would induce duration compression compared with a stimulus followed by smooth pursuit. Eight subjects were instructed to observe a stimulus displayed on a monitor and follow it with their eyes. In the pursuit condition, the stimulus moved smoothly and continuously. In the saccade condition, the stimulus jumped from one place to another. Stimulus motion in each condition was derived from the same pattern; thus, the same trajectory was used in the two conditions. The subjects then compared a moving stimulus to a static stimulus and answered which seemed to last longer. In both pursuit and saccade conditions, the stimuli were perceived to last longer than the static stimulus ($p < 0.001$). Furthermore, the amount of time dilation in the saccade condition (point of subjective equality [PSE] = 122% of the static stimulus) was larger than that in the pursuit condition (PSE = 113%, $p = 0.006$). In summary, even when objects move through the same trajectory, the duration differed depending on the eye movements. Saccade resulted in a longer perceived duration, contrary to our hypothesis.

Acknowledgement: KAKENHI-16H03749, 17K18693, 25119003

26.458 **Uncertainty of the Internal Duration Template Dilates Subjective Time** Yong-Jun Lin[1](yjlin@nyu.edu), Shinsuke Shimojo[1]; [1]Computation and Neural Systems, California Institute of Technology

Everybody knows roughly how long one second lasts. How does such an internal duration template affect perceived time? We investigated an illusion where the first visual item in a repeating sequence appears to last longer ("debut chronostasis"). Earlier studies explained this either by increased attention towards the first item or relatively suppressed neural encoding for the repeated ones. However, previous studies overlooked two confounding factors by keeping the first item the target with variable duration across trials. First, the target defined by instruction may create a cognitive bias (instruction effect). Second, the variable item across trials may implicitly draw more attention or activate memory encoding processes, so as to modulate perceived time (uncertainty effect). In a duration discrimination task (Experiment 1), the three target-reference pairs were defined by instruction as 1st-2nd, 2nd-1st, and 2nd-3rd in separate blocks. As expected, 1st-2nd produced chronostasis and 2nd-3rd did not. In the novel 2nd-1st condition, debut chronostasis was largely reduced. This excluded the attention and the repetition suppression hypotheses because both predict the same illusion in the 1st-2nd and 2nd-1st conditions, leaving the instruction or the uncertainty effects as plausible explanations. In Experiment 2, the explicit instruction was the same regarding which item was the target, but the variable item was the reference instead. The results supported the uncertainty, but not the instruction effect. In both experiments, the relative duration between the 2nd and the 3rd items did not significantly differ; only when the first item had uncertain duration across trials, debut chronostasis occurred. Therefore, an internal duration template based on recent stimuli history may be calibrated at the first item per trial and disrupted when the first time varies in duration. Future studies shall take this newly-identified effect into account, and investigate how the first-item uncertainty leads to time expansion rather than compression.

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26.459 **The effects of figure-ground segmentation on non-linear visual evoked potentials** Laila E Hugrass[1](lhugrass@swin.edu.au), David P Crewther[1]; [1]Centre for Human Psychopharmacology, Swinburne University of Technology

The neural correlates of figure-ground segmentation have been studied using single cell responses in primate thalamus and visual cortex, as well as fMRI in humans. In order to study the non-linear temporal structure of figure-ground responses in human observers, we recorded chromatic multifocal visual evoked potentials. The stimuli were radial gratings with the slightly elongated edges, which gave the appearance of an object on a background. The gratings were separated into inner and outer rings of patches that alternated between red and green in independent pseudorandom binary sequences (refresh rate = 60Hz). Hence, we were able to use Weiner kernel analyses to extract independent responses to each of the inner patches. When the red-green alternations were equiluminant, there was no clear figure-ground modulation of the multifocal VEP responses. When there was a small luminance difference between the red and green levels, we observed a decrease in the first-slice of the second order non-linear response to figure patches relative to ground patches. This difference was evident at latencies as early as 80ms. These results suggest that global analysis of a stimulus can influence responses to local luminance defined edges at very early stages of visual processing.

Acknowledgement: Australian Research Council

26.460 **Saccadic and Movement Reaction Time discrimination in humans** Valentina Vencato[1,2](vvale68@gmail.com), Joan López-Moliner [3], Laurent Madelain[1,2]; [1]SCALab, Université Lille 3 (France), [2]Institut de Neurosciences de la Timone, Aix-Marseille Université (France), [3]Universitat de Barcelona (Spain)

We have previously established that saccadic reaction times (SRTs) may depend on reinforcement contingencies. It follows that one must be able to discriminate one's own latencies to adequately assign credit to one's actions. In two different experiments we used an adaptive procedure to test the limit of both saccadic and manual reaction time (MRTs) in ten subjects for each experiments. In the first experiment we trained ten participants using a staircase paradigm to determine their 75% perceptual threshold of SRTs. On each trial they had to saccade to a stepping target. In a 2-AFC task they had to choose the number representing the actual SRT while the second number was a made-up value which proportionally differed from this SRT. The relative difference between the two options was computed by either adding or subtracting one of the percentage values of a decreasing fixed staircase range. To encourage learning a feedback was provided after each response. In the MRTs experiment participants reached a target and judged their reaction time in a 2AFC task. The protocol was similar to the SRTs experiment, except that we used a double staircase in a QUEST procedure. In this case the relative difference between the two numbers quickly converge to threshold. 75% threshold was computed by fitting a psychometric function for both experiments. Results reveal a very accurate perception both of SRTs and MRTs: 75% threshold range from 13% for the best performance to the 37% for the worst one in the SRTs discrimination and from 12% to 36% for MRTs perception. This indicates that our participants can discriminate very small SRT differences, providing support for the possibility that the credit assignment problem may be solved even for short reaction times.

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26.461 **Beyond binning: Getting more out of the time course of one-sample-per-trial data** Jonathan van Leeuwen[1](jvanleeuwen.work@gmail.com), Jeroen B.J. Smeets[2], Artem V. Belopolsky[1]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit, Amsterdam, The Netherlands, [2]Department of Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands

When researchers are interested in the time course of data which consists of one-sample-per-trial (e.g. accuracy as a function of reaction time), they usually split the data into time bins (also known as Vincentizing). In some cases an arbitrary number of bins is used, which, as we demonstrate, can significantly misrepresent the underlying signal. Several researchers circumvented this problem by smoothing the time course using a Gaussian kernel. A major problem for this method is missing data, as well as inability to perform proper statistical analysis on the smoothed time course. In the analysis of neural time series there is a long history of using permutation testing for determining statistical significance. However, this method assumes a complete time series for each trial and therefore cannot be directly applied to one-sample-per-trial data. Here we present a novel method that combines the improved smoothing of one-sample-per-trial data with permutation testing. We show that this method can be used to visualize the time course and to perform statistical testing for differences between conditions, as well for differences against a predetermined baseline. The method is demonstrated using eye-tracking data (saccade curvature), as well as psychophysical data (accuracy) and compared against two common methods of binning data. The advantages and disadvantages of this method are discussed.

Acknowledgement: Open Area Research Grant from the Netherlands Organization for Scientific Research

Motion: Neural mechanisms and models

Saturday, May 19, 2:45 - 6:45 pm

Poster Session, Pavilion

26.462 **The dynamics of optic flow during natural locomotion** Jonathan Samir Matthis[1](matthis@utexas.edu), Karl S Muller [1], Mary M Hayhoe[1]; [1]Center for Perceptual Systems, University of Texas at Austin

A long history of research on the visual control of locomotion has explored the role of optic flow in the regulation and guidance of human walking, but the optic flow stimulus experienced during natural locomotion has never been recorded. To this end, we used optic flow estimation algorithms to measure head-centered optic flow recorded from the head-mounted camera of a mobile eye tracker. The traditional view of optic flow holds that the Focus of Expansion (FoE) lies in a stable location in the walker's direction of travel. In contrast, our analysis shows that the acceleration patterns of the head during gait cycle cause the FoE to move constantly at very high velocities within the walker's field of. Thus it is unlikely to be useful for controlling heading. In contrast, when we recalculated optic flow in a retinal reference frame, we found flow patterns that were far more regular than those seen in the head-centered reference frame. Thus it seems unnecessary to "correct" for the effects of eye movements on retinal optic flow in order to recover the FoE in the head-centered optic flow, as has generally been thought. Rather, the gaze stabilization reflexes that allow for fixation during locomotion simplify the visual motion patterns on the retina. Fixation nulls motion at the fovea, resulting in regular patterns of outward flow. This regularization should increase a walker's sensitivity to the subtle variation of flow velocity and orientation that specify 3D structure-from-motion information. These results therefore cast doubt on the idea that walkers use the FoE to control heading, but suggest a critical role of visual motion information for the perception of the 3D scene structure and a possible role in the control of posture during locomotion.

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26.463 **The effect of relative size on the interactions between motion sensors tuned to fine and coarse scale** Sandra Arranz-Paraiso[1](sandraar@ucm.es), Ignacio Serrano-Pedraza[1,2]; [1]Faculty of Psychology. Complutense University of Madrid, Madrid, 28223, Spain, [2]Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, NE2 4HH, UK

Motion discrimination of high spatial-frequency stimuli is impaired when a static low spatial-frequency component is added to it. However, motion discrimination is facilitated when a static high-frequency component is added to a low-frequency moving stimulus (Serrano-Pedraza et al., 2013 JoV). Previous studies show that this interaction between motion sensors tuned to fine and coarse scales depends on the relative contrast and size of both coarse and fine scale stimuli (Serrano-Pedraza & Derrington, 2010, JoV). In this experiment, we extend these studies by testing the effect of the relative size of the high- and low-frequency components in order to measure the contribution of each motion sensor to the mechanism responsible for this interaction. Using Bayesian staircases, we measured duration thresholds for 7 subjects in a motion discrimination task. We used vertical Gabor patches of frequencies 1 and 3c/deg and 28% contrast. Four conditions were tested, 1 c/deg moving, 3c/deg moving, 1 static added to a 3 c/deg moving (1s+3m), and 1c/deg moving added to a 3c/deg static (1m+3s). For each condition, five different diameters (2Sxy) were used (0.5, 1, 2, 3, & 4deg), therefore testing in total 30 combinations of different sizes. Our results show that duration thresholds for the condition 1s+3m increase with increasing size, and the strongest suppressive interaction is reached when the size of both components is maximum. However, for the condition 1m+3s, we found the opposite behavior: duration thresholds decrease with increasing size. For the biggest sizes, we found a facilitation effect: duration thresholds were lower than the thresholds for detecting the condition 1m with the same size. The analysis of the results from relative sizes, suggest that the size of the high spatial-frequency component is the relevant dimension for the activation of the motion mechanism underlying this interaction between motion sensors tuned to different scales.

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26.464 **Motion perception in 360 degrees** Giyeul Bae[1](freebird71@gmail.com), Steven Luck[1]; [1]Center for Mind and Brain, University of California Davis

Random dot kinematograms (RDKs) have been used to study motion perception for decades, but almost all studies involve a binary choice (e.g., leftward vs. rightward). By allowing the direction to vary over 360° with various coherence levels, and by asking the participant to report the exact direction of motion in continuous 360° space, we were able to observe three interesting phenomena that cannot be observed in the traditional discrete alternative choice task. First, we found that participants often have the illusion that the motion is in the opposite of the true direction (180° errors). Second, the perceived direction of motion is biased away

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from the cardinal axes (which may serve as implicit category boundaries). Third, observers make two distinct kinds of errors: normally distributed errors around the true motion direction, and uniformly distributed errors over the all possible motion directions. This suggests that behavioral performance reflects a mixture of trials in which the motion was perceived with some degree of precision and trials in which the true stimulus direction was not detected at all. By applying a mixture model, we were able to estimate the precision on trials where the motion was detected and the probability that the motion was not detected. Both of these parameters were systematically influenced by the coherence level and the stimulus duration. Together, these findings provide new insights into the perception of motion and into perceptual decision-making in a context where the decision space is continuous rather than discrete.

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26.465 **Motion perception and form discrimination in psychiatric patients.** Mariagrazia Benassi[1](mariagrazia.benassi@unibo.it), Federica Ambrosini[2], Roberta Raggini[2], PatriziaRosa Sant'Angelo[2], Giovanni De Paoli[2], Sara Giovagnoli[1], Claudio Ravani[3], Giovanni Piraccini[2]; [1]Department of Psychology, University of Bologna, [2]Psychiatric Emergency Unit Ausl della Romagna-Cesena, Italy, [3]Psychiatric Unit Ausl della Romagna, Italy

Former studies have suggested that schizophrenia and bipolar disorders (BPD) are associated with a deficiency in the magnocellular visual system. Nevertheless, these findings are still controversial. The aim of the present study is to analyze whether visual processing is affected in schizophrenia, BPD, and depression patients and to investigate whether these deficits are associated with symptoms severity, neuropsychological function and eye movements. Thirty psychiatric inpatients, with diagnoses of Schizophrenia, Depression, and Bipolar Disorder participated in the study. Symptoms severity was measured with Brief Psychiatric Rating Scales. Accuracy in motion and form perception was evaluated by motion and form coherence tests respectively. Smooth pursuit eye movements were measured with Eye Tribe infrared video-oculography system. Data were analyzed off-line to calculate gain, delay and maximum speed. The general cognitive abilities were tested by Raven's Matrices. Stroop Test and Attentive Matrix were used to assess attention and Digit Span Test for memory. Executive functions were evaluated using Tower of London test and a modified version of Wisconsin Card Sorting Test. All the scores were standardized according to age and gender. No significant differences emerged between psychiatric diagnostic groups concerning motion and form perception and eye movements parameters. When compared to the control group, patients showed impaired visual perception and higher delay and lower gain values. Linear regression analysis showed that motion perception performances were related significantly to general cognitive abilities, attention ability, executive functions and ocular motility and did not depend to symptoms severity. Form recognition was only related to executive functions. These preliminary findings confirm the hypothesis that visual perception deficits in psychiatric patients are related to cognitive impairment and oculomotor defects .

26.466 **A model grounded in natural scene statistics predicts human performance with both natural and artificial stimuli** Benjamin M Chin[1](bechin@sas.upenn.edu), Johannes Burge[2]; [1]Department of Psychology, University of Pennsylvania, [2]Department of Psychology, University of Pennsylvania

Models developed with artificial stimuli tend to generalize poorly to natural stimuli. Do models developed with natural stimuli generalize well to artificial stimuli? We examine this question in the context of motion estimation. Accurate estimation of self-motion and of the motion of objects in the environment is critical for survival and reproduction, but the visual system must first accurately estimate the motion of images on the retina. Previously, we developed an ideal observer for retinal speed estimation with natural image movies and used it to tightly predict human responses in a speed discrimination experiment with a single efficiency parameter ($R2>0.95$; Chin & Burge, 2017). We further showed that the value of the efficiency parameter nicely predicts human response agreement with natural stimuli in a double-pass experiment, a result predicted by the hypothesis that inefficiency is due only to internal noise. How well does this ideal observer predict human performance with artificial stimuli? Here, with zero additional free parameters, we challenged the ideal observer to predict human speed discrimination and human response agreement in a double-pass experiment. Each human observer performed a speed discrimination experiment with drifting Gabors in a 2IFC design (1deg, 250ms) using the method of constant stimuli, and each observer performed the experiment twice (2800 trials = 2 standard speeds x 7 levels/standard x 100 trials/level x 2 passes). The ideal observer predicts i) a 30% improvement in thresholds compared to natural stimuli, and ii) significantly less response agreement between passes. Both predictions are confirmed by the data. These results show that careful task-specific analysis of natural signals can provide powerful (and interpretable) models that predict human performance with both natural and artificial stimuli.

26.467 **The perceptual representation of "space" defined by motion versus color** Kara J Emery[1](karaemery@nevada.unr.edu), Vicki J Volbrecht[2], David H Peterzell[3], Michael A Webster[1,4]; [1]Graduate Program in Integrative Neuroscience, University of Nevada, Reno, Reno, NV 89557, [2]Department of Psychology, Colorado State University, Fort Collins, CO 80523, [3]College of Psychology, John F. Kennedy University, Pleasant Hill, CA, USA, [4]Department of Psychology, University of Nevada, Reno, Reno, NV 89557

Individual differences in color appearance are large and reliable among color-normal observers, but it remains unclear what processes underlie these differences. In a recent factor analysis of hue-scaling functions, we found that variability depended on multiple, narrowly-tuned processes, consistent with a multichannel or population code in which different "directions" in color space are represented separately. To gain insights into this representation, we examined individual differences in the perception of motion, which like color is defined by three cardinal, and in this case, Cartesian dimensions. We designed a motion scaling task similar to hue scaling, where observers judged the strength of up/down and left/right percepts in a moving stimulus (analogous to decomposing a hue into red/green and blue/yellow percepts). The stimulus was a 2^0 circular aperture of dots moving coherently in one of 36 possible directions at 10^0 intervals along the 2D plane. The directions were displayed in random order and were pulsed repeatedly along the same trajectory until observers recorded their response. Settings for twenty-three observers were factor-analyzed using PCA and Varimax rotation. The analysis revealed approximately four systematically-tuned factors (i.e. with significant loadings on two or more adjacent stimuli). Together these accounted for 60% of the total variance. The first factor's loadings varied roughly sinusoidally with a period of 180^0, consistent with differences in the relative weighting of horizontal vs. vertical. The second factor corresponded to variations relative to both the cardinal axes and diagonals (~sinusoidally varying with a period of 90^0). Unlike the narrow factors for color, the factors for motion had a global pattern of loadings consistent with a metrical representation of space in terms of the underlying Cartesian axes. These results suggest that while color and motion share a common dimensional structure, the perceptual representation of color- and motion-defined space may be fundamentally different.

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26.468 **Effect of 10Hz Transcranial Alternating Current Stimulation (tACS) on Motion Direction Identification** Xizi Gong[1](gongxizi0730@pku.edu.cn), Fang Fang[1,2,3,4]; [1]School of Psychological and Cognitive Sciences, Peking University, Beijing, China, [2]IDG/McGovern Institute for Brain Research, Peking University, Beijing, China, [3]Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China, [4]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China

tACS is a noninvasive method to modulate brain oscillation and functions. Although there is rapidly growing interest in using tACS to modulate visual perception (e.g., motion perception) in humans, previous findings are inconsistent and some of them have been shown to be unreliable. Here, we recruited 11 subjects and tested the tACS effect on their motion direction identification. One electrode was place at PO7-PO3 in the 10-20 EEG system (left hemisphere) and the other electrode was placed on the vertex (Cz). We used a sinusoid current (1 mA peak to peak) at a frequency of 10 Hz, which was delivered during visual stimulus presentation. Visual stimuli were random dot kinematograms (RDKs) consisting of 700 dots. The dots moved at a velocity of 3°/s within a virtual circular area subtending 10° in diameter. The center of the aperture was positioned 7° horizontally to the left or right of the central fixation point. The coherence level of the RDKs could be 0%, 2%, 4%, 8%, or 16% and those coherent dots moved either upward or downward. Each of the nine stimuli (i.e., a combination of coherence level and motion direction) were presented 50 times and each presentation lasted 4 sec. Subjects needed to make a two-alternative forced-choice (2-AFC) judgment to identify the global motion direction (either upward or downward). Eye movement was recorded to ensure that subjects' eye positions were within a 2° window around fixation. We found that, relative to the no-tACS condition, subjects' motion identification accuracy could be significantly improved by 10Hz tACS. The improvement occurred when the stimulus were presented in either the left or the right visual field. Our finding demonstrated that visual motion perception could be enhanced by tACS and suggest that the mechanisms underlying the enhancement might not be restricted to retinotopic visual areas.

26.469 **Predictive coding of visual object position ahead of moving objects revealed by time-resolved EEG decoding** Hinze Hogendoorn[1,2](Jhahogendoorn@gmail.com), Anthony N Burkitt[3]; [1]Melbourne School of Psychological Sciences, The University of Melbourne, Melbourne, Australia, [2]Helmholtz Institute, Department of Experimental Psychology, Utrecht University, Utrecht, the Netherlands, [3]Department of Biomedical Engineering, The University of Melbourne, Australia

Due to the delays inherent in neuronal transmission, our awareness of sensory events necessarily lags behind the occurrence of those events in the world. If the visual system did not compensate for these delays, we would consistently mislocalize moving objects behind their actual position. Anticipatory mechanisms that might compensate for these delays have been reported in animals, and such mechanisms have also been hypothesized to underlie perceptual effects in humans such as the Flash-Lag Effect. However, to date no direct physiological evidence for anticipatory mechanisms has been found in humans. Here, we apply multivariate pattern classification to time-resolved EEG data to investigate anticipatory coding of object position in humans. By comparing the time-course of neural position representation for objects in both random and predictable apparent motion, we isolated anticipatory mechanisms that could compensate for neural delays when motion trajectories were predictable. As well as revealing an early neural position representation (lag 80-90 ms) that was unaffected by the predictability of the object's trajectory, we demonstrate a second neural position representation at 140-150 ms that was distinct from the first, and that was pre-activated ahead of the moving object when it moved on a predictable trajectory. The latency advantage for predictable motion was approximately 16±2 ms. To our knowledge, this provides the first direct experimental neurophysiological evidence of anticipatory coding in human vision, revealing the time-course of predictive mechanisms without using a spatial proxy for time. The results are numerically consistent with earlier animal work, and suggest that current models of spatial predictive coding in visual cortex can be effectively extended into the temporal domain.

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26.470 **Integration of position and predictive motion signals in older adults** Hyun-Jun Jeon[1](n37jun13e@unist.ac.kr), Yeojeong Yun[2], Oh-Sang Kwon[1]; [1]Department of Human Factors Engineering, Ulsan National Institute of Science and Technology (UNIST), Republic of Korea, [2]Department of Energy and Chemical Engineering, Ulsan National Institute of Science and Technology (UNIST), Republic of Korea

Motion induced position shift (MIPS) and slow speed bias (SSB) are suggested to be consequences of optimal integration of position and motion signals (Kwon et al., 2015). It implies MIPS and SSB are proper tasks to characterize individual differences in position-motion integration. We measured the magnitudes of MIPS and SSB in older and young adults to examine the aging effects on position-motion integration. METHODS: 24 elderly and 21 young adults participated in Experiment 1. In a trial, each MIPS stimulus was presented in both sides of visual fields (eccentricities 5°, 10°, or 15°) for 1s. Subjects had to judge the relative heights of stimuli in a position task and the relative speeds of stimuli in a speed task. The magnitudes of MIPS and SSB were measured for three eccentricities. In Experiment 2, 10 elderly and 8 young adults participated. The identical stimulus as in Experiment 1 (eccentricity 10°) was presented for a duration that varied between 31ms and 1000ms. The size of MIPS was measured as a function of stimulus durations. RESULTS: The MIPS sizes of elderly observed in three eccentricities (0.63°, 0.86°, 1.03°) were 2.5 times larger than those of young participants (0.13°, 0.24°, 0.40°) on average. As a function of duration, two groups showed a similar trend in that the magnitudes of MIPS peaked around 56ms-97ms (Young: 0.39°, Elderly: 0.77°) and stabilized at lower magnitudes. The SSB magnitude significantly increased as eccentricity increases, but group difference was not significant (Young: 1.14°/s, 2.11°/s, 2.87°/s, Elderly: 0.27°/s, 1.50°/s, 2.82°/s). DISCUSSIONS: The result that MIPS magnitude doubled in elderly group implies older adults would rely more on motion signals in visual tracking possibly due to large positional uncertainties. Results of Experiment 2 suggest that aging has a minimal impact on the time for the integration of position and motion signals.

26.471 **Hyper-upregulation of abnormally low neural response along the visual pathway in autism** tamar kolodny[1](tamar.kolodny@gmail.com), Rachel Millin[1], Michael-Paul Schallmo[1,2], Alex M Kale[1], Raphael A Bernier[3], Scott O Murray[1]; [1]Department of Psychology, University of Washington, Seattle, WA, [2]Department of Psychiatry, University of Minnesota, Minneapolis, MN, [3]Department of Psychiatry and Behavioral Science, University of Washington, Seattle, WA

A unifying theme of numerous proposals of the pathophysiology of autism spectrum disorder (ASD) is that it results from a pervasive alteration in neural excitability. However, the various forms of evidence implicating neural excitability appear contradictory. On one hand, a well-known hypothesis is that ASD might reflect an increase in excitation/inhibition (E/I) balance and hyper-excitability of cortical circuits. However, other evidence from animal models has pointed to the opposite hypothesis – that ASD can be characterized by a reduction in E/I balance resulting from reduced excitability. It has recently been suggested that both perspectives – over- and under-excitability – can be reconciled in a framework that takes into account the propagation of information in neural circuits and homeostatic mechanisms that stabilize neural responses. We used the well-established hierarchical structure of human visual motion processing to test the hypothesis that there is abnormal coupling of responses between visual areas in individuals with ASD. We used fMRI to measure neural responses to moving gratings of varying contrast in early visual cortex (EVC) and in human MT complex (hMT+), a motion selective region in the lateral occipital lobe that receives direct input from EVC. Our findings demonstrate that, among neurotypical participants, neural response magnitudes correlate between these brain regions: individuals with relatively high responses in EVC also have high responses in hMT+. On the contrary, among individuals with autism, there is a negative relationship between the magnitude of contrast responses in EVC and the magnitude of response in hMT+. Specifically, participants with abnormally low responses in EVC exhibit abnormally high responses in hMT+. Interestingly, the degree of abnormality in the neural responses correlates with severity of clinical symptoms of ASD. Our findings may suggest that compensatory homeostatic processes are dysregulated along the visual pathway, over-enhancing signals as they propagate through the visual system.

26.472 **Speed uncertainty and motion perception with naturalistic random textures** Kiana Mansour Pour[1](kiana.mansourpour@gmail.com), Nikos Gekas[2], Laurent Perrinet[1], Pascal Mamassian[2], Anna Montagnini[1], Guillaume S. Masson[1]; [1]institut de Neurosciences de la Timone, UMR 7289, CNRS, Aix-Marseille Universite , Marseille 13005, France, [2]Laboratoire des Systèmes Perceptifs, Département d'études cognitives, École normale supérieure, PSL Research University, CNRS, 75005 Paris, France

It is still not fully understood how visual system integrates motion energy across different spatial and temporal frequencies to build a coherent percept of the global motion under the complex, noisy naturalistic conditions. We addressed this question by manipulating local speed variability distribution (i.e. speed bandwidth) using a well-controlled class of broadband random-texture stimuli called Motion Clouds (MCs) with continuous naturalistic spatiotemporal frequency spectra (Sanz-

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Leon et al., 2012, ; Simoncini et al., 2012). In a first 2AFC experiment on speed discrimination, participants had to compare the speed of a broad speed bandwidth MC (range: 0.05-8°/s) moving at 1 of 5 possible mean speeds (ranging from 5 to 13 °/s) to that of another MC with a small speed bandwidth (SD: 0.05 °/s), always moving at a mean speed of 10°/s. We found that MCs with larger speed bandwidth (between 0.05-0.5°/s) were perceived moving faster. Within this range, speed uncertainty results in over-estimating stimulus velocity. However, beyond a critical bandwidth (SD: 0.5 °/s), perception of a coherent speed was lost. In a second 2AFC experiment on direction discrimination, participants had to estimate the motion direction of moving MCs with different speed bandwidths. We found that for large band MCs participant could no longer discriminate motion direction. These results suggest that when increasing speed bandwidth from small to large range, the observer experiences different perceptual regimes. We then decided to run a Maximum Likelihood Difference Scaling (Knoblauch & Maloney, 2008) experiment with our speed bandwidth stimuli to investigate these different possible perceptual regimes. We identified three regimes within this space that correspond to motion coherency, motion transparency and motion incoherency. These results allow to further characterize the shape of the interactions kernel observed between different speed tuned channels and different spatiotemporal scales (Gekas et al., 2017) that underlies global velocity estimation.

Acknowledgement: European Union's Horizon 2020 research

26.473 **Search inefficiency in a directionally consistent target among directionally switching distractors** Hoko Nakada[1](hoko@g.ecc.u-tokyo.ac.jp), Ikuya Murakami[1]; [1]Department of Psychology, The University of Tokyo

Visual search is efficient when observers search for a moving target among static distractors and that search efficiency is equally high for a static target among moving distractors. However, visual motion often compromises search efficiency, as when all search items are moving, making search based on other features rather inefficient. Based on these effects of the presence of motion signals on visual search, we asked whether more complex motion signals such as directional reversal could affect search efficiency. To address this question, we used moving gabor patches as search items and reversed their motion directions over time during a visual search task. In one condition, the target was a gabor patch that periodically switched its motion direction whereas the remaining items, the distractors, maintained their motion directions. In another condition, the target maintained its motion direction whereas the distractors periodically switched their directions altogether. If the presence of visual motion per se disturbed search, both tasks should cause inefficient search. If, on the other hand, motion direction switching generally facilitated search, both tasks should cause efficient search. Furthermore, if the direction switching served as a salient feature, search asymmetry should emerge because a more salient item among less salient distractors would be easier to find than vice versa. Our results indeed demonstrated search asymmetry. Search was efficient for the directionally changing target among the consistently moving distractors, but was inefficient when the target consistently moved while the distractors changed their directions. This search asymmetry supported the hypothesis that motion direction switching is a salient feature in a visual search task for moving stimuli. Through a series of experiments, we clarified the determinant factor in motion direction switching that caused the search asymmetry, testing for possible factors such as orientation, acceleration, and synchrony.

Acknowledgement: IM was supported by a JSPS KAKENHI grant number 25119003.

26.474 **Stimulus predictability affects reconstruction of dynamic visual objects in early visual cortex** Sunyoung Park[1](suny5803@gmail.com), Won Mok Shim[1,2]; [1]Center for Neuroscience Imaging Research, Institute for Basic Science (IBS), [2]Department of Biomedical Engineering, Sungkyunkwan University (SKKU)

Previous work showed that features interpolated during apparent motion (AM) are represented in the population-level feature responses in primary visual cortex, indicating that the brain fills in details that are absent in raw sensory inputs but are reconstructed during dynamic object transformations via top-down processes (Chong, Familiar, & Shim, 2016). Predictive coding accounts hypothesize that feedback can suppress responses in early sensory cortex when incoming sensory information is predicted by top-down expectations. However, it remains unclear how top-down, filled-in neural representations in early visual cortex are modulated by the predictability of the sensory input. Using fMRI and an inverted encoding model, we examined how neural representations of interpolated features during dynamic filling-in evolves as our prediction builds up, and how they are affected by the predictability of the moving object's trajectory. A gabor patch that was oriented radially to the central fixation, was sequentially presented in each quadrant to induce rotational AM along the circular trajectory. AM trajectory was either predictable, where the gabor appears to move in one direction (clockwise or counterclockwise), or unpredictable, where the direction appears to randomly change. Consistent with the previous finding, regions in V1 retinotopically mapped to the AM path showed feature-selective responses for orientation interpolated during AM. Such responses were absent in the first cycle of AM, implying that information about the overall motion trajectory needs to be extracted first. Crucially, after the first cycle, the feature-selective responses were stronger when the trajectory was unpredictable, compared to when it was predictable by top-down expectations. Our finding is consistent with the predictive coding hypothesis, and suggests that top-down representations of filled-in features in early visual cortex can be created after the initial prediction for the object dynamics is formed, but suppressed later via feedback when the uncertainty of the upcoming sensory input is low.

Acknowledgement: This work was supported by IBS-R015-D1.

26.475 **Exploring the Uncanny Valley** Flip Phillips[1](flip@skidmore.edu), Filipp Schmidt[2], Laura Noejovich[1], George Chakalos[1]; [1]Neuroscience & Psychology, Skidmore College, [2]Experimental Psychology, Justus Liebig University Gießen

As robots become more human-like our appreciation of them increases — up to a crucial point where we find them realistic but not perfectly so. At this point, human preference plummets into the so-called uncanny valley. This phenomenon isn't limited to robotics and has been observed in many other areas. These include the fine arts, especially photorealistic painting, sculpture, computer graphics, and animation. The informal heuristic practices of the fine arts, especially those of traditional animation, have much to offer to our understanding of the appearance of phenomenological reality. One interesting example is the use of exaggeration to mitigate uncanny valley phenomena in animation. Raw rotoscoped imagery (e.g., action captured from live performance) is frequently exaggerated to give the motion 'more life' so as to appear less uncanny. We performed a series of experiments to test the effects of exaggeration on the phenomenological perception of simple animated objects — bouncing balls. A physically plausible model of a bouncing ball was augmented with a frequently used form of exaggeration known as squash and stretch. Subjects were shown a series of animated balls, depicted using systematic parameterizations of the model, and asked to rate their plausibility. A range of rendering styles provided varying levels of information as to the type of ball. In all cases, balls with no exaggeration (e.g., veridically) were seen as significantly less plausible than those with it. Furthermore, when the type of ball was not specified, subjects tolerated a large amount of exaggeration before judging them as implausible. When the type of ball was indicated, subjects narrowed the range of acceptable exaggeration somewhat but still tolerated exaggeration well beyond that which would be physically possible. We contend that, in this case, exaggeration acts to bridge the uncanny valley for artificial depictions of physical reality.

26.476 **The limits of apparent motion perception in the praying mantis** Jenny Read[1](jenny.read@ncl.ac.uk), Lisa Jones[1], Candy Rowe[1], Claire Rind[1], Vivek Nityananda[1], Ghaith Tarawneh[1]; [1]Institute of Neuroscience, Newcastle University

When a visual pattern is displaced in small jumps, if the jumps are small and close enough in time, we perceive the pattern as moving smoothly. As the jumps become larger, the apparent motion becomes choppy, until eventually, beyond the maximum displacement "Dmax", we cannot distinguish the direction of motion at all [1]. In humans, Dmax increases with the size of the pattern elements [2]. We repeated this experiment in the praying mantis, varying the size and jump interval so as to keep the mean speed constant at 12.5cm/s. The stimulus was a random chequerboard with 100% contrast, filling a CRT screen 7cm in front of the insect; the elements are the chequer squares. For small displacements, stimuli reliably elicited an optomotor response: the mantis moved in the direction

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of the displacement. As the displacement increased, the probability of an optomotor response fell to zero. We defined Dmax for a given element size as the displacement which elicited an optomotor response on 50% of trials. We found that in the praying mantis as in humans, the plot of Dmax against element size is a straight line on log axes. In mantises, Dmax increases roughly as the square root of element size. In humans, Dmax tends to become independent of element size for the smallest elements. This is believed to reflect the scale of spatial filtering before motion extraction [2]. In mantises, no such limit is observed: Dmax continues to decrease with element size down to the smallest values tested. We suggest this is because insect vision does not have a separate stage of spatial filtering which precedes motion extraction; rather, motion detection occurs at the earliest stages of insect vision. 1. Braddick (1974). Vision Research 14, 519-527 2. Morgan (1992). Nature 355 344-346

Acknowledgement: Leverhulme Trust

26.477 **Aging and the estimation of visual motion direction** Lindsey M Shain[1](lindsey.shain327@topper.wku.edu), J. Farley Norman[1]; [1]Psychological Sciences Department, Ogden College of Science and Engineering, Western Kentucky University

The perception of motion is subject to the aperture problem. When extended contours move behind occluding apertures, only the component of motion perpendicular to the orientation of the contour can be detected. The direction of contour motion is thus ambiguous. The visual system can solve the aperture problem and recover the true direction of object motion by integrating across multiple ambiguous motion signals. The stimulus displays were essentially identical to those of Mingolla, Todd, & Norman (1992). Rectangular arrays of 64 and 9 apertures were presented to 20 younger and older observers (mean ages were 22.1 and 74.3 years); each aperture contained a randomly-oriented line segment. The entire array of line segments moved together behind the apertures in one of 12 possible directions (zero to 330 degrees relative to vertical). Once each line segment reached its aperture's edge, it was recycled back to the opposite side; each line segment thus never left its respective aperture. The stimulus duration for each of the 120 trials per observer (2 aperture conditions x 12 directions of pattern motion x 5 repetitions) was 2.4 sec. The observers were required to estimate the exact direction of pattern motion (over the range of zero to 360 degrees) by adjusting the orientation of a pointer that appeared after the termination of each stimulus display. The results indicated that the younger observers' average error for estimating the direction of pattern motion was 9.4 and 26.2 degrees for the 64 and 9 aperture conditions, respectively. The errors of the older observers' direction judgments were higher: 22.0 degrees for the 64 motion signals/apertures condition and 35.0 degrees for the 9 motion signals/apertures condition. Despite some modest deterioration in accuracy, the current results demonstrate that older adults can effectively integrate locally ambiguous motion signals into a coherent perception of motion direction.

26.478 **Short-latency ocular-following responses to motion stimuli are strongly affected by temporal modulations of the visual content during the initial fixation period.** Boris Sheliga[1](bms@lsr.nei.nih.gov), Christian Quaia[1], Edmond J FitzGibbon[1], Bruce G Cumming[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health, Bethesda, MD 20892

Neuronal and psychophysical responses to a visual stimulus are known to depend on the preceding history of visual stimulation, but the effect of stimulation history on reflexive eye movements has received less attention. Here we quantify these effects using short-latency ocular following responses (OFRs), a valuable tool for studying early motion processing. We recorded, in three human subjects, the horizontal OFRs induced by drifting vertical 1D pink noise. The stimulus was preceded by 600-1000 ms of maintained fixation (on a visible cross), and we explored the effect of different stimuli ("fixation patterns") presented during the fixation period. We found that any temporal modulation present during the fixation period reduced the magnitude of the subsequent OFRs. The magnitude of the effect was a function of both spatial and temporal structure of the fixation pattern. Suppression that was selective for both relative orientation and relative spatial frequency accounted for 50-57% of total suppression. Even brief changes in the overall luminance of fixation patterns induced significant suppression. Finally, changes in stimulus temporal structure alone (i.e., 'flicker' vs 'transparent motion') led to changes in the spatial frequency tuning of suppression. In the time domain, the suppression developed quickly: 100 ms of temporal modulation in the fixation pattern produced up to 80% of maximal suppression. Recovery from suppression was instead more gradual, taking up to several seconds. By presenting transparent motion during the fixation period, with opposite motion signal having different spatial frequency content, we also discovered a direction-selective component of suppression, which depended on both the frequency and the direction of the moving stimulus.

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Sunday Morning Talks

Faces: Recognition and perception

Sunday, May 20, 8:15 - 9:45 am, Talk Room 1

Moderator: Alice O'Toole

31.11, 8:15 am **A learned generative model of faces for experiments on human identity**

Jordan W Suchow[1](suchow@berkeley.edu), Joshua C Peterson[1], Thomas L Griffiths[1]; [1]Department of Psychology, University of California, Berkeley

Generative models of human appearance and identity have broad applicability to the study of face perception, but the exquisite sensitivity of human face perception means that their utility hinges on alignment of the latent representation to human psychological representations and the photorealism of the generated images. Meeting these requirements is an exacting task, and existing models of human identity and appearance are often unworkably abstract, artificial, uncanny, or heavily biased. Here, we use a variational autoencoder with an autoregressive decoder to learn a latent face space from a uniquely diverse dataset of portraits that control much of the variation irrelevant to human identity and appearance. Our method generates photorealistic portraits of fictive identities with a smooth, navigable latent space. We validate our model's alignment with human sensitivities by introducing a psychophysical Turing test for images, which humans mostly fail, a rare occurrence with any interesting generative image model. We describe several applications of the learned face space to experiments on face perception, memory, and learning.

Acknowledgement: DARPA NGS2

31.12, 8:30 am **Hierarchical Representations of Viewpoint and Illumination in Deep Convolutional Neural Networks Trained for Face Identification**

Matthew Q Hill[1](mattqhill@gmail.com), Connor J. Parde[1], Jun-Cheng Chen[2], Carlos D. Castillo[2], Volker Blanz[3], Alice J. O'Toole[1]; [1]Behavioral and Brain Sciences, The University of Texas at Dallas, [2]Institute for Advanced Computer Studies, The University of Maryland, [3]Institute for Vision and Graphics, University of Siegen

Deep convolutional neural networks (DCNNs) have defined the state-of-the-art in automatic face identification in recent years, but the nature of the information encoded in the top-level features of these networks is still poorly understood. To probe these deep feature representations, we utilized a face identification DCNN (Chen, Patel, & Chellappa, 2016) trained with 494,414 face images of 10,575 identities. These training images varied widely in illumination, viewpoint, and quality (blur, facial occlusion, etc.). We used this DCNN to process face images rendered from a highly controlled dataset of laser-scanned faces (Troje & Bülthoff, 1996). The images were rendered to vary systematically in viewpoint and illumination for each of 133 faces (65 male). Specifically, each face was rendered from 5 viewpoints (0˚ [frontal], 20˚, 30˚, 45˚, and 60˚), and under two illumination conditions (ambient vs. off-center spotlight). This yielded 10 images per face. A Receiver Operating Characteristic (ROC) curve showed excellent identification performance for the DCNN on the dataset (area under the ROC = 0.997). Next, we used t-distributed Stochastic Neighbor Embedding (t-SNE) to compress the top-level feature map into two dimensions to visualize the effect of viewpoint and illumination in the DCNN similarity space. The t-SNE showed that illumination and viewpoint clustered hierarchically, as follows. The largest grouping in this t-SNE space divided males and females into two large clusters. Within the gender clusters, each image clustered according to its respective identity. Within each identity cluster, the two illumination conditions separated into sub-clusters. Remarkably, within each illumination condition there was a "chain" of systematically varying viewpoints. This hierarchical pattern indicates that although the DCNN features were optimized for identification, within-identity photometric variables were well represented in the top-level deep features. These results illustrate how photometric information can co-exist with identity in a representation optimized only for the latter.

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31.13, 8:45 am **Disrupting features in faces: Configural representations or interaction with foveated vision?**

Yuliy Tsank[1](yuliy.tsank@psych.ucsb.edu), Miguel P. Eckstein[1], Xiao (Nicole) Han[1]; [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara

Performance in human face discrimination tasks can be degraded by manipulating the position of features (i.e. eyes, nose, mouth) within a face stimulus (Tanaka & Farah, 1993). The effect is typically attributed to a disruption of face mechanisms in the brain involving feature configuration (de Haas et al. 2016). Here, we use an ideal observer (IO) and a foveated ideal observer (FIO; Peterson & Eckstein, 2012), to investigate the extent to which that performance difference can be attributed to the interaction between the altered feature locations and the sampling of foveated processing arising from eye movement strategies. We create a fixation-weighted FIO (FW-FIO) in order to control for effects on performance caused by the observers' empirical fixation strategies. Methods: Six observers completed an emotion discrimination task with three emotions (happiness, sadness, and fear) using movies of 20 faces (15 deg. height, 1400ms presentation) in luminance noise. Four conditions were used; a control upright face, a face with inverted (upside down) features with intact locations, and two different anomalous configurations of upright facial features. Observers were free to execute eye movements. Results: The efficiency of both humans and the FW-FIO compared to the IO is significantly lower for configurations in which important features for the task (eyes and mouth) are further away from each other relative to those configurations in which they are closer together and cannot be foveated simultaneously. However, humans compared to the FW-FIO, have even lower efficiency in the altered configurations relative to the control configuration. Conclusion: Our findings suggest that much of the degradation in performance with altered facial feature configurations can be attributed to the interaction between foveated processing and the location of features relative to observers' fixations. However, there is a residual efficiency loss related to other configuration specific mechanisms higher in the visual stream.

31.14, 9:00 am **A role for contrast gain control in face perception**

Richard Russell[1](rrussell@gettysburg.edu), Carlota Batres[1], Alex L. Jones[2], Aurélie Porcheron[3,4]; [1]Gettysburg College, [2]Swansea University, [3]Chanel Research & Technology, [4]LPNC, Université Pierre Mendès-France

Introduction Apparent contrast can be suppressed or enhanced when presented within surrounding images. This contextual modulation is typically accounted for by models of contrast gain control. Here we report in face perception the existence of effects similar to contextual modulation. In five experiments we increased or decreased contrast between facial skin and adjacent image regions to determine whether this modulates the appearance of skin evenness and wrinkles. Methods and Results We first found that an occluding grid placed over images of skin affected ratings of skin evenness. Skin appeared more even when the grid was black than when its luminance matched the skin tone. In a subsequent experiment with full-face images we found that skin appeared less wrinkled and more even when occluded by black bars than skin-toned bars. We next manipulated contrast by keeping the skin unchanged but increasing or decreasing the luminance and color of the facial features. Again, skin appeared more even and less wrinkly when contrast was increased. Critically, this was found for inverted as well as upright faces, consistent with a low-level contrast mechanism but not a face-specific mechanism. In a final experiment, we applied typical makeup to the facial features but no products were applied to the skin. Despite the skin appearance being physically identical, skin appeared more even and less wrinkled when makeup was applied to the features. Conclusions We showed that facial skin appearance is affected by contrast with adjacent surfaces. This includes contrast with the facial features, which can be modified through makeup. Preliminary evidence indicates that other forms of personal decoration such as hair coloring, clothing, and jewelry can also affect skin appearance through contrast suppression or enhancement. This suggests the exciting possibility of linking such cultural practices to the structure and function of the visual system.

31.15, 9:15 am **The speed of human face categorization** Talia L Retter[1,2](tlretter@nevada.unr.edu), Fang Jiang[2], Bruno Rossion[1,3]; [1]The University of Louvain, Belgium, [2]The University of Nevada, Reno, USA, [3]Centre Hospitalier Regional Universitaire, France

Faces can be discriminated from other objects in the visual environment with astonishing speed (100-150 ms). However, a selective electrophysiological response to faces persists for a relatively long time (over 400 ms) in the human brain (Retter & Rossion, 2016). Here, we determined 1) the minimal stimulus presentation duration required to elicit a face-categorization response; moreover, we investigated 2) the effect of increasing image presentation duration on the amplitude, spatial, and temporal aspects of face-categorization responses, and 3) the relationship of these neural effects with behavioral face categorization responses. We recorded high-density EEG from 16 naïve observers with ascending 63-s series of natural object images at nine presentation durations, from 8 to 333 ms (120 to 3 Hz), throughout which temporally masked faces appeared consistently every 1 s (1 Hz). In a second experiment with the same, debriefed participants, we presented temporally masked faces non-periodically within shorter sequences, each at a constant frequency, with an explicit face detection task. The results showed a significant face-categorization response at 1 Hz emerging with 33-ms of presentation at the group level, varying from 17-83 ms across individual participants. Most importantly, we observed a general increase in the amplitude of the face-categorization response as presentation duration increased, but the correspondence of this effect with behavioral accuracy suggests that lower 1-Hz amplitudes were largely driven by missed detections. Across presentation durations, face-categorization responses displayed similar occipito-temporal topographies and sequences of temporal deflections. Thus, we propose that a face-selective response is mainly all-or-none, occurring occasionally to faces at extremely short viewing times and becoming more consistent, but not more evolved, as presentation duration increases (up to about 50-80 ms). One practical implication of these results is that, at least for measuring face categorization electrophysiologically with young adults, (masked) presentation durations exceeding 80 ms are not required.

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31.16, 9:30 am **Holistic Processing of Conscious and Unconscious Faces** Haiyang Jin[1](haiyang.jin@auckland.ac.nz), Paul M. Corballis[1], Matt Oxner[1], William G. Hayward[2]; [1]School of Psychology and Centre for Brain Research, The University of Auckland, Auckland, New Zealand, [2]Department of Psychology & ARC Centre for Cognition and Its Disorders, The University of Hong Kong, Hong Kong

Previous research suggests that holistic face processing is implicated in face recognition. However, little is known about the role of consciousness in holistic face processing. The present study explores the holistic processing of conscious and unconscious faces. Holistic processing was measured by the composite task, in which composite faces were created by combining top and bottom regions of two different faces, and participants were asked to judge if the top halves of two consecutive composite faces were the same or not. Holistic face processing is typically observed in the composite task through interference on judgments of the target (top) halves from variations in the irrelevant (bottom) halves of faces. In addition, continuous flash suppression (CFS) was utilized to present some stimulus components unconsciously. In Experiment 1 (E1), participants performed the composite face task with the irrelevant bottom halves of faces presented consciously (monocular) or unconsciously (CFS). Results showed that the composite effect was only found in the conscious condition, but not in the unconscious condition. To test whether the bottom halves of faces could be processed at all in the unconscious condition, the following experiment embedded catch trials in the composite tasks. In the catch trials, the bottom half (irrelevant) of the presented composite, along with the bottom half of a novel composite were presented and participants were asked to choose the one they saw. As in E1, the composite effect was only observed when irrelevant components were consciously perceived. However, identification performance of bottom halves on the catch trials was above chance, showing that participants did have access to some information about them, but this information did not affect judgments of the target (top) halves of faces in the composite task. Taken as a whole, these results show that unconscious face information does not appear to be processed holistically.

Color and Light: Lower level

Sunday, May 20, 8:15 - 9:45 am, Talk Room 2

Moderator: Rhea Eskew

31.21, 8:15 am **Accommodation, chromatic aberration and chromatic stimuli** Abigail P Finch[1](abigail.p.finch@durham.ac.uk), Maydel Fernandez Alonso[2], Jenny C A Read[2], Gordon D Love[1]; [1]Department of Physics, Durham University, Durham, United Kingdom, [2]Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, United Kingdom

The eye has substantial longitudinal chromatic aberration (LCA) of approximately 2 dioptres (D) across the visible spectrum. Under normal broadband illumination, our eyes focus approximately in the middle of the spectrum (i.e. on green wavelengths). However, it is unclear how we accommodate to spectra composed of multiple narrowband components. This is relevant for current types of lighting and displays, which often have relatively narrowband sources. Understanding this will also give an insight into the way the visual system uses various cues in order to accommodate. Our aim was to investigate accommodation to lights with two narrowband components. We measured participants' accommodative responses using an autorefractor. The stimulus was a black Maltese cross mounted on a diffuser presented at 3D from the participant and viewed monocularly. The stimulus was back illuminated by five LEDs, each with a different narrow emission spectrum. We presented various mixtures of pairs of these LEDs. For each mixture, we measured the static accommodative response. We also calculated the accommodative response that would optimise image quality in the luminance pathway for each mixture. The calculations showed that typically image quality would be optimised for the mixtures by accommodating to one of the two individual LEDs. However, the observed responses differed from this. Often participants accommodated somewhere in-between the two wavelengths. One possible explanation for this finding is that rather than accommodating to maximise the image quality, participants were accommodating to reach a certain ratio between the image quality in different cone channels. Under natural broadband illumination this behaviour could provide a good approximation of the best image quality. However, with these unnatural spectra this tactic is no longer effective. Acknowledgements: We would like to thank Martin S. Banks for his ideas and support with this project.

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31.22, 8:30 am **Ray-tracing 3D Spectral Scenes Through Human Optics** Trisha Lian[1](tlian@stanford.edu), Kevin J MacKenzie[2], Brian Wandell[3]; [1]Electrical Engineering, Stanford University, [2]Oculus Research, [3]Psychology, Stanford University

Background. Display technology design benefits from a quantitative understanding of how parameters of novel displays impact the retinal image. Vision scientists have developed many precise computations and facts that characterize critical steps in vision, particularly at the first stages of light encoding. ISETBIO is an open-source implementation that aims to provide these computations. The initial implementation modeled image formation for distant or planar scenes. Here, we extend ISETBIO by using computer graphics and ray-tracing to model how spectral, three-dimensional scenes are transformed by human optics to the retinal irradiance. Methods. Given a synthetic 3D scene, we trace rays using PBRT (Physically Based Ray-Tracer) through an optical model of the human eye to obtain the spectral irradiance at the retina. The optical model specifies wavelength-dependent index of refraction and surface parameters; these are chosen to match the curvature, size, and asphericity of the cornea, lens, and retina. The methods can implement other eye models, including those with biconic surfaces. The simulation accounts for the chromatic dispersion of light in different ocular media, as well as the effects of accommoda-

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tion and pupil size. Results. We compare the retinal irradiance generated from the simulation with experimental measurements from the literature. The sharpness of the computed retinal image matches statistical models. Further, the longitudinal chromatic aberration in our renderings closely matches experimental data. Conclusion. The ray tracing calculations enable us to understand the impact of different 3D display parameters on the retinal spectral irradiance. This ability may also prove useful for understanding the information available to the visual system to perform critical tasks, such as accommodation and vergence. The simulation tools are available in the ISETBIO Github repository.

31.23, 8:45 am **Color contrast gain in anomalous trichromats** John E Vanston[1](jvanston1206@gmail.com), Katherine EM Tregillus[1], Michael A Webster[1], Michael A Crognale[1]; [1]Department of Psychology, College of Liberal Arts, University of Nevada, Reno

Anomalous trichromats have three cone types, but with diminished L vs M sensitivity due to shifted spectral sensitivities. We examined whether post-receptoral processing might amplify and thus compensate for these receptoral sensitivity losses. Compensation is predicted if – like color normals – the visual system of anomals adapts to match visual coding for their visual environment. Results from previous studies investigating this have been mixed, but recent evidence points to compensation in some tasks. The current study used threshold detection and two measures of suprathreshold perception (contrast matching and reaction times for discriminating color differences) to compare contrast coding in normal and anomalous observers. LM contrast thresholds were substantially higher in anomals. They also required more LM contrast to match a suprathreshold reference stimulus. However, the contrast losses were greater for thresholds than the suprathreshold matches. For each task, we modeled the cone-opponent signal expected from differences in the peak separation of the L and M cones. For anomals, the separation predicted by suprathreshold contrast matching was nearly twice that predicted by detection thresholds, suggesting neural compensation. Reaction times were measured at several contrast levels along the four cardinal directions of cone-opponent space. Anomals had slower average reaction times, consistent with a weaker contrast response, but had nearly identical reaction times at the highest contrast level, indicating a stronger contrast dependence. However, unlike the contrast matching, deficits were also observed for stimuli that varied in S cone contrast. This suggests that under the stimulus conditions used, the reaction times of anomalous trichromats cannot be accounted for by simple gain adjustments for their sensitivity losses.

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31.24, 9:00 am **Illusory colors from harmonic combinations: an unexpected consequence of ON and OFF pathways** Andrew T Rider[1](a.rider@ucl.ac.uk), Bruce Henning[1], Rhea T Eskew Jr.[2], Andrew Stockman[1]; [1]UCL Institute of Ophthalmology, University College London, [2]Department of Psychology, Northeastern University, Boston

We report an exciting new visual illusion that also provides a novel method of investigating early visual processing. When superimposed red and green lights are sinusoidally flickered in opposite phase at moderate temporal frequencies they take on a mean yellow appearance. However, adding second, third, or fourth harmonics to the flicker can dramatically change the mean colour appearance from yellow towards either red or green depending on the temporal alignment of the added harmonics, even though the mean chromaticity and luminance remain unchanged. Perceiving different mean colours in stimuli that have physically identical time-averaged characteristics points to the interposition of significant nonlinearities in the chromatic pathway. To investigate these colour shifts we varied the frequency and phases of different harmonic combinations of red/green flicker around the same physical mean. In spatial 2AFC tasks, observers indicated which appeared redder out of two polarity inverted waveforms presented in two semi-circular 5.7° fields. Measurements were made on carefully calibrated and linearized CRTs. Although the results appear complex, we can accurately predict the colour shifts using a relatively simple, yet physiologically plausible model, in which cone signals are first linearly filtered (presumably in the photoreceptors themselves), then half-wave rectified into ON and OFF pathways (at the cone-bipolar synapse). Signals in these two pathways are passed through later linear filters, then through saturating nonlinearities (presumably cortical saturating contrast response functions). Depending on the input phase alignments reaching the rectification stages, radically different signals are passed to the ON and OFF pathways, which are then differentially compressed by the late nonlinearity to produce an average imbalance in the signals and thus a colour shift. This phenomenon provides a powerful new tool for psychophysically dissecting the red-green chromatic pathway, and we expect other pathways.

Acknowledgement: BBSRC grants BB/I003444/1 and BB/M00211X/1 to AS and NSF grant BCS-1353338 to RTE.

31.25, 9:15 am **fMRI adaptation reveals interactions between responses to achromatic and S-cone isolating stimuli across visual cortex** Erin Goddard[1](erin.goddard@mcgill.ca), Robert F Hess[1], Kathy T Mullen[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Canada

Introduction: We used fMRI adaptation to investigate cortical selectivity to S-cone isolating (BY) and achromatic (Ach) stimuli. Previous work (Mullen et al, EJN, 2015, doi: 10.1111/ejn.13090) shows that for red-green (RG) and Ach contrast, there is increasing RG color selectivity in the higher ventral areas, especially VO. Here we used a similar paradigm to test the selective of responses to BY/Ach stimuli. Methods: We measured BOLD adaptation (3T scanner, TR=3s, 1.5 or 3mm isovoxels) to BY/Ach stimulus pairs (n=12), using similar methods to Mullen et al 2015. Both adapting and test stimuli were sinewave counter-phasing rings (0.5cpd, 2Hz), presented in a counterbalanced block design of adapt/no adapt, test and fixation blocks, with 96 repeats/subject. We used standard retinotopic mapping and localisers to define 9 ROIs (V1, V2, V3, V3a/b, LO, hMT, hV4, VO1 and VO2) and analysed data using AFNI/SUMA. Results: Across visual cortex, we found robust adaptation for all adaptor/test stimulus combinations (BY/BY, Ach/Ach, BY/Ach and Ach/BY). Across the 9 ROIs there was no significant main effect of either test or adaptor stimulus, but there was a significant interaction between these effects ($F(1,385) = 9.23$, $p< 0.01$). Ach test stimuli have a greater signal loss following BY than Ach adaptation, while BY tests had similar signal loss for both adaptors. Interestingly, the interaction was in the opposite in direction to that expected, with greater cross-stimulus adaptation than within-stimulus adaptation. Conclusion: Our data suggest that the S-cone pathway has qualitatively different interactions with cortical responses to Ach contrast than to RG. Responses to BY and Ach contrast are unselective across the cortical areas tested, unlike previous results for RG/Ach stimuli. The cross-adaptation of S-cone isolating stimuli on achromatic responses reveals an unexpected non-linear effect that is not accounted for by conventional stimulus adaptation models.

Acknowledgement: CIHR grants (MOP-10819) to KTM and (MOP-53346) to RFH

31.26, 9:30 am **Luminance response functions in the human visual cortex** Louis N Vinke[1,3](vinke@bu.edu), Sam Ling[2,3]; [1]Graduate Program for Neuroscience, Boston University, Boston, Massachusetts, USA, [2]Department of Psychological and Brain Sciences, Boston University, Boston, Massachusetts, USA, [3]Center for Systems Neuroscience, Boston University, Boston, Massachusetts, USA

Models of early cortical visual processing typically downplay the role of mean luminance in the neural coding of visual signals, emphasizing instead the coding of features such as relative contrast. Since the visual system is tasked with encoding surfaces and objects in scenes, which often vary independently in local luminance and contrast, it seems plausible that luminance information is encoded and plays an influential role in visuocortical processing. Indeed, electrophysiological studies in animals have found that increasing mean luminance levels multiplicatively increased the gain of contrast response functions in V1, most apparent at high contrast levels. In this study, we explored the degree to which different mean luminance levels can drive the early visual cortex in humans, using fMRI. We measured BOLD responses in early visual cortex (V1-V3) while participants viewed checkerboard stimuli that varied in contrast and mean luminance. Our experimental paradigm allowed us to reliably measure luminance response functions between 49 and 1278 cd/mm2 at two extreme contrast levels (4% and 96% Michelson Contrast),

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and at multiple spatial scales (voxel-wise and retinotopic). To control for changes in pupil diameter with varying luminance levels, stimuli were viewed monocularly through an artificial pupil. We found that luminance response functions in early visual cortex are contrast dependent. At high contrast, linearly increasing the mean luminance level produced a nonlinear increase in BOLD response. At low contrast, a flat BOLD response was observed across all mean luminance levels. These results reveal that the visuocortical neural code can represent information corresponding to changes in the mean luminance of a visual signal, and is most prominent at high contrast levels.

Visual Memory: Cognitive neuroscience

Sunday, May 20, 10:45 am - 12:30 pm, Talk Room 1

Moderator: Caitlin Mullin

32.11, 10:45 am **Evidence for non-frontal control of sensory working memory** Thomas B Christophel[1](tbchristophel@gmail.com), Chang Yan[1], Lee Stopak[1], Stefan Hetzer[1], John-Dylan Haynes[1-5]; [1]Bernstein Center for Computational Neuroscience and Berlin Center for Advanced Neuroimaging and Clinic for Neurology, Charité Universitätsmedizin, corporate member of Freie Universität Berlin, Humboldt Universität zu Berlin, and Berlin Institute of Health, [2]Berlin School of Mind and Brain, Humboldt Universität, Berlin, Luisenstraße 56, Haus 1, Berlin, 10099, Germany, [3]Cluster of Excellence NeuroCure, Charité Universitätsmedizin, corporate member of Freie Universität Berlin, Humboldt Universität zu Berlin, and Berlin Institute of Health, Berlin, Charitéplatz 1, Hufelandweg 14, Berlin, 10117, Germany, [4]Department of Psychology, Humboldt Universität zu Berlin, Rudower Chaussee 18, Berlin, 12489, Germany , [5]SFB 940 Volition and Cognitive Control, Technische Universität Dresden, Zellescher Weg 17, 01069 Dresden, Germany

Items held in visual working memory can be quickly updated, replaced, removed and even manipulated in accordance with behavioral goals. Current views postulate that memorized contents are represented by mnemonic activity distributed across the full cortical hierarchy. It has however remained unclear which neural mechanism exert control over these distributed stores to select what items should be remembered and which can be forgotten. Here, we use multivariate pattern analyses (MVPA) to identify fMRI activity patterns representing executive control processes supervising these flexible stores. In the task, subjects had to memorize two stimuli - one visual grating and one auditory tone that were sequentially presented. After an extensive delay, a cue stimulus instructed the subjects whether the first or the second stimulus should be used for a successive change discrimination task (at the same time also implying which stimulus could be forgotten). Multivariate decoding indicated that memory for the cued item persisted throughout the 30 second trial and mnemonic activity selectively declined when the item was dropped from memory. To identify areas involved in control, we used MVPA to identify activity patterns that are selectively carrying information regarding the instruction conveyed by the cue ('first stimulus' or 'second stimulus'). We found that transient neural activity in inferior parietal and superior temporal cortices carried information about what items should be retained during cue presentation. These selection-specific activity patterns generalized across both numerical and alphabetical selection cues. We found no such evidence in prefrontal cortex. In summary, we our findings point to posterior, but not frontal areas as carrying information to exert control of distributed stores. Thus, our results suggest that selection of memorized items can be controlled in a distributed and decentralized fashion thus questioning the notion of a prefrontal central executive supervising all working memory function.

32.12, 11:00 am **Posterior alpha and frontal delta oscillations interactively support priority switches within visual working memory.** Ingmar EJ de Vries[1](i.e.j.de.vries@vu.nl), Joram van Driel[1], Christian NL Olivers[1]; [1]Department of Experimental and Applied Psychology, Faculty of Behavioral and Movement Sciences, Vrije Universiteit Amsterdam.

Visual search is assumed to be guided by an active visual working memory representation of what we are currently looking for. This attentional template can be dissociated from accessory memory representations that are only needed prospectively, for a future task, and that until then should be prevented from guiding attention. Little is known about how the brain sequentially prioritizes, and switches between memory representations for successive task goals. We measured EEG while human observers performed two consecutive working memory-guided visual search tasks. Prior to the first search task, a cue instructed observers which item to look for first (current template), and which second (prospective template). During the first delay, leading up to the first of the two searches, posterior alpha power (8-14 Hz) was more suppressed contralateral to the memory item. These lateralized alpha dynamics were stronger if the lateralized item was the imminent search target (current template), than when it was the subsequent search target (prospective template). To investigate the electrophysiological mechanisms underlying the switch in priority, on 40% of the trials an auditory cue replaced the first search, telling observers that at this point the first template could be dropped, in favor of now prioritizing the second, prospective template. Dropping the first template resulted in clear alpha enhancement, while turning the former prospective template into the current search target resulted in alpha suppression. Furthermore, this switch in posterior alpha lateralization was predicted by an increase in frontal delta/low theta (2–6 Hz) power. This increase in low-frequency power in frontal regions also predicted faster response times on the second search task. We thus obtained evidence for large-scale network interactions during the flexible "juggling" between priority states of multiple memory items in between search tasks.

Acknowledgement: ERC Consolidator grant ERC-2013-2013-CoG-615423 to CNLO

32.13, 11:15 am **Decoding the limits of simultaneous storage in working memory** Kirsten Adam[1](kadam1@uchicago.edu), Edward K. Vogel[1], Edward Awh[1]; [1]Department of Psychology, University of Chicago

Competing models of visual working memory (WM) make strongly diverging claims about the number of items that can be held actively in mind. These include: (1) no limit in the number of items, but a degradation in quality with more remembered items (2) a capacity limit of around 3 items, or, even (3) a single prioritized item in the focus of attention. Behavioral tests of these models are useful but fundamentally limited – even if participants cannot report an item at test, it is still possible that they actively represented the item during maintenance. Thus, a method that enables simultaneous decoding of the specific items maintained in WM would provide powerful traction for this debate. Here, we made significant advances toward this aim by attempting to decode the locations of all actively maintained items from multi-item arrays using the topography of alpha-band power (8-12 Hz) in the human EEG signal. In Experiment 1 (n=31), colored squares appeared in three of eight possible location bins equidistant from fixation. Participants were pre-cued to 1, 2, or 3 relevant items with centrally presented spatial cues (small lines pointing toward the location/s). We found reliable decoding of 2 items simultaneously, counter to predictions of a single focus of attention model. In Experiment 2 (n=20), participants were presented with 1, 3, or 6 items. Critically, for set size 6 arrays, evidence for active storage was restricted to the 3 best –remembered items, while there was no active neural signal tracking the remaining items. Thus, neural signals that track WM storage in an item-specific manner rule out models in which all items are stored equally imprecisely, and suggest strict limits on the number of items that can be actively maintained.

32.14, 11:30 am **Drift in fMRI pattern representations during the delay interval predicts performance in a visual working memory task** Phui Cheng Lim[1](cheng.lim@unl.edu), Emily J Ward[2], Timothy J Vickery[3], Matthew R Johnson[1]; [1]Department of Psychology, College of Arts and Sciences, University of Nebraska-Lincoln, [2]Department of Psychology, College of Letters & Science, University of Wisconsin-Madison, [3]Department of Psychological and Brain Sciences, College of Arts & Sciences, University of Delaware

Previous studies have found that individuals maintain brain activity patterns across a working memory (WM) delay that are similar to the patterns exhibited during the initial perception of remembered items. Additionally, greater pattern similarity between encoding and recall is associated with greater chances of successful memory performance. In

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this fMRI study, we used a Delayed-Match-to-Sample visual WM task to investigate how ongoing changes in brain activity patterns throughout the delay interval corresponded with WM performance. On each trial, participants (n=20) viewed a target Gabor patch and were instructed to remember it using a visualization strategy throughout an eleven-second delay interval. They then saw a probe patch that either matched or did not match the target's orientation. Target and probe orientations were drawn from a set of six evenly spaced orientations, with the spacing determined by an earlier staircasing procedure to achieve approximately 75% accuracy for each participant. Non-matching probes were always chosen from an orientation adjacent to the target's. We calculated fMRI pattern similarity in visual cortex between the target representation and each subsequent timepoint in the trial. Pattern drift was defined as changes in pattern similarity during the delay interval towards or away from a given orientation's prototypical activity pattern. In trials where the target and probe orientations were the same, participants were more likely to incorrectly report the orientations did not match when their activity patterns drifted away from the target orientation and towards target-adjacent orientations. In trials where the target and probe orientations were different, participants were more likely to incorrectly report the orientations matched when their activity patterns drifted towards the orientation of the non-matching probe patch. Our results suggest that errors in working memory tasks are not simply due to unstructured noise, but also drift within representation space that can be indexed by neuroimaging.

Acknowledgement: NSF/EPSCoR grant #1632849 to MRJ, TJV, and colleagues

32.15, 11:45 am **The Genesis of Visual Memory through Strong Perceptual Representations: Tracking the Spatio-Temporal Neural Trace of Memorability** Caitlin R Mullin[1](crmullin@mit.edu), Yalda Mohsenzadeh [1,2], Dimitrios Pantazis [2], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, MIT, [2]McGovern Institute for Brain Research, MIT

Memory encoding is traditionally associated with the end stages of visual processing. However, not all images are perceived equally — some images carry a greater perceptual capacity and thus may have a higher likelihood of being remembered. How does the brain process these perceptually strong images compared to those that fade away? Here we tested the hypothesis that more memorable images show a greater neural perceptual trace (robust and sustained brain signals) than those that are less memorable. We collected MEG and fMRI data while participants viewed stimuli of low and high memorability scores from the LaMem Memorability image set (Khosla et al., 2015). The stimuli were balanced for low-level image statistics and high-level semantic content. To track the neural signals of memory through perception with high resolution in space and time, we coupled MEG and fMRI data (Cichy et al., 2014; 2016) using representational similarity analysis (Kriegeskorte et al., 2008). Results revealed that more memorable images recruited the medial and lateral regions of the ventral-visual processing stream to a greater degree than the less memorable images (Bainbridge et al., 2017). Importantly, by 100ms after image onset, we found a more robust representation for high memorable images in the fusiform gyrus, lateral occipital and parahippocampal cortices. The neural representations of memorable images were more sustained in time both during (online perception) and after (iconic memory) image presentation. This robust and sustained representation found in high level brain regions for more memorable images could point to the perceptual maintenance required to stimulate the visual system to encode the information into long-term memory. These findings challenge the assumption that memory and perception are functionally and anatomically segregated by demonstrating that we can trace the path of memorability early on through perceptual regions, prior to memory encoding.

Acknowledgement: Vannevar Bush Faculty Program ONR N00014-16-1-3116 to A.O. - NSF award 1532591 to A.O & D.P.

32.16, 12:00 pm **Simultaneous representation of mnemonic and sensory information in human visual cortex** Rosanne L Rademaker[1](rosanne.rademaker@gmail.com), Chaipat Chunharas[1], John T Serences[1,2,3]; [1]Psychology department, University of California San Diego, La Jolla, California, USA, [2]Neurosciences Graduate Program, University of California San Diego, La Jolla, California, USA, [3]Kavli Institute for Brain and Mind, University of California, San Diego, La Jolla, California, USA

Traversing everyday sensory environments often requires representing information about relevant features or objects in memory while simultaneously processing new sensory inputs. Although early visual cortex demonstrates persistent modulation of featureselective neural responses during short term memory maintenance, recent work suggests that visual cortex can only represent the contents of memory, or the characteristics of new sensory inputs, but not both. Here we provide evidence that population-level response patterns in visual cortex can concurrently represent information about the contents of short term memory alongside the specific features of new sensory inputs. This multiplexing capacity in classic 'sensory' areas may support a local circuit for computing a 'match' signal between behaviorally relevant but no longer visible features, and new sensory stimuli.

Acknowledgement: This work was supported by NEI R01-EY025872 and a James S McDonnell Foundation Scholar Award to JTS, and by the European Union's Horizon 2020 research and innovation program under the Marie Sklodowska-Curie Grant Agreement No 743941 to RLR.

32.17, 12:15 pm **Decoding item-specific information in visual short-term memory from the hippocampal DG/CA3 subfield using high-resolution fMRI** Weizhen Xie[1](weizhen.xie@email.ucr.edu), Marcus Cappiello[1], Michael Yassa[2], Edward Ester[3], Gopikrishna Deshpande[4], Weiwei Zhang[1]; [1]Department of Psychology, University of California, Riverside, [2]Department of Neurobiology and Behavior, University of California, Irvine, [3]Department of Psychology, Florida Atlantic University, [4]Department of Electrical and Computer Engineering, Auburn University

Human memory does not always retain accurate mental representations that precisely correspond to the exceedingly rich contents in natural vision. This functional limit can be attributed to a reduction in precision of internal representations from visual perception to visual short-term memory (VSTM). The mechanism underlying this bottleneck in representational precision remains a topic of controversy. One class of theories attributes VSTM precision to neural noise in sustained neural activities that support VSTM retention. In contrast, another class of theories maintains that VSTM retention and mnemonic precision are supported by dissociable and independent neural mechanisms. For example, the level of neural noise in sustained neural activities for VSTM, which manifests as mnemonic precision of VSTM, may be determined by hippocampal pattern separation, a computational process that orthogonalizes similar memories into non-overlapping representations. To test this hippocampal pattern separation hypothesis, the present study adopted Harrison and Tong's (2009) orientation VSTM paradigm with high-resolution fMRI. Using the inverted decoding model, we decoded item-specific information from the hippocampal dentate gyrus (DG) and CA3 subfield, a brain region previously implicated in pattern separation, during the delay interval of the VSTM task. In contrast, item-specific information could not be reliably decoded from the hippocampal CA1 subfield or the amygdala. A whole-brain searchlight analysis revealed some additional areas in occipital, posterior parietal, and prefrontal cortices that carry item-specific information, replicating some previous findings. Furthermore, Granger causality analyses identified a feedback projection from the hippocampal DG/CA3 to visual cortices during the delay interval, potentially linking hippocampal pattern separation to sensory reactivation of precise representation. Overall, these findings support a novel hippocampal pattern separation hypothesis for mnemonic precision, which is central to the ongoing debate on the nature of the limits in VSTM.

Eye Movements: Performance

Sunday, May 20, 10:45 am - 12:30 pm, Talk Room 2

Moderator: Miriam Spering

32.21, 10:45 am **Extending DeepGaze II: Scanpath prediction from deep features** Matthias Kümmerer[1](matthias.kuemmerer@bethgelab.org), Thomas S.A. Wallis[1,2], 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

Predicting where humans choose to fixate can help understanding a variety of human behaviour. The last years have seen substantial progress in predicting spatial fixation distributions when viewing static images. Our own model “DeepGaze II” (Kümmerer et al., ICCV 2017) extracts pretrained deep neural network features from the VGG network from input images and uses a simple pixelwise readout network to predict fixation distributions from these features. DeepGaze II is state-of-the-art for predicting freeviewing fixation densities according to the established MIT Saliency Benchmark. However, DeepGaze II predicts only spatial fixation distributions instead of scanpaths. Therefore, the models model ignores crucial structure in the fixation selection process. Here we extend DeepGaze II to predict fixation densities conditioned on the previous scanpath. We add additional feature maps encoding the previous scanpath (e.g. the distance of image pixels to previous fixations) to the input of the readout network. Except for these few additional feature maps, the architecture is exactly as for DeepGaze II. The model is trained on ground truth human fixation data (MIT1003) using maximum-likelihood optimization. Even using only the last fixation location increases performance by approximately 30% relative to DeepGaze II and reproduces the strong spatial fixation clustering effect reported previously (Engbert et al., JoV 2015). This contradicts the way Inhibition of Return has often been used in computational models of fixation selection. Using a history of two fixations increases performance further and learns a suppression effect around the earlier fixation location. Due to the probabilistic nature of our model, we can sample new scanpaths from the model that capture the statistics of human scanpaths much better than scanpaths sampled from a purely spatial distribution. The modular architecture of our model allows us to explore the effects of many different possible factors on fixation selection.

Acknowledgement: German Science Foundation (DFG Collaborative Research Centre 1233: Robust Vision: Inference Principles and Neural Mechanisms, TP03).

32.22, 11:00 am **The impact of retinal image motion on extrafoveal sensitivity** Janis Intoy[1](jintoy@bu.edu), Norick R Bowers[2], Jonathan D Victor[3], Martina Poletti[4,6], Michele Rucci[5,6]; [1]Graduate Program for Neuroscience, Boston University, [2]Vision Science Graduate Group, UC Berkeley, [3]Brain and Mind Research Institute, Weill Cornell Medical College, [4]Department of Neuroscience, University of Rochester, [5]Department of Brain & Cognitive Sciences, University of Rochester, [6]The Center for Visual Science, University of Rochester

Humans are not aware that their eyes are always moving, even during the inter-saccadic periods of “visual fixation” in which visual information is acquired and processed. In these periods, ocular drift continually shifts the image on the retina, converting spatial luminance patterns into temporal signals impinging onto retinal receptors. Previous work has shown that the visual system is sensitive to these modulations and uses them to enhance sensitivity to high spatial frequencies (Kuang et al, 2012; Boi et al, 2017). These effects likely play an important role in driving the responses of neurons in the foveola. However, it is commonly assumed that drift carries little impact outside of the foveola, where drift covers a smaller fraction of the larger receptive fields. Contrary to this widespread assumption, we show that drift improves sensitivity to high spatial frequencies even without foveal stimulation. We measured contrast sensitivity in seven observers as they reported the orientation (±45o) of 16 cpd gratings with controlled retinal image motion. We simulated the retinal effects of larger and smaller drifts by amplifying or attenuating retinal motion from normal drift by means of a real-time system for gaze-contingent display. An artificial scotoma (1o-diameter) was fully stabilized to the center of gaze to prevent foveal stimulation. We report several findings. First, we show that vision outside of the foveola benefits from ocular drift: discrimination is impaired when drift is eliminated. Second, normal retinal image motion optimizes performance: larger and smaller drifts reduce sensitivity. Third, models of retinal ganglion cells exposed to the same stimulation fully account for how sensitivity varies with the amount of retinal image motion. These findings indicate that the spatiotemporal input reformatting from eye drift exerts its action throughout the visual field. They suggest that individual deviations from normal drift may impair visual sensitivity.

Acknowledgement: Supported by NIH R01 EY018363 and NSF grants BCS-1457283 and BCS-1420212

32.23, 11:15 am **Signatures of a probabilistic strategy in the control of saccadic eye movements** Matteo Lisi[1](matteo.lisi@city.ac.uk), Joshua A Solomon[1], Michael J Morgan[1]; [1]Centre for Applied Vision Research, City University of London

Saccades are rapid eye movements that orient the visual axis toward objects of interest to allow their processing by the central, high-acuity part of the retina. Our ability to collect efficiently visual information from the environment relies on the accuracy of saccades, which is limited by a combination of uncertainty in the location of the target and motor noise (van Beers, 2007). Additionally, saccades have a systematic tendency to fall short of their intended targets (hypometria), which is thought to result from a deliberate strategy that seeks to minimize a cost function favouring hypometric errors (e.g. Harris, 1995). In this study, we tested whether this strategy is probabilistic, i.e. whether it seeks to minimize the expected cost of saccadic errors by taking into account uncertainty in a statistically principled way. We asked observers to judge the location of peripheral targets, or make saccades to them, and manipulated their sensory uncertainty by varying the blurriness of the targets. Location judgments became more variable with increased blurriness, confirming the effectiveness of our manipulation. Most interestingly, increasing uncertainty resulted not only in larger spread of the saccade endpoints, but also in more hypometric errors, and in less frequent and more variable corrective saccades. Moreover, under high uncertainty, saccade endpoints were biased toward the average of target locations in a given block, suggesting that prior knowledge was integrated into saccade planning. In sum, we report that saccades made under varying levels of uncertainty about target location do indeed carry the signatures of a probabilistic-Bayesian strategy.

Acknowledgement: Leverhulme Trust RPG-2016-124

32.24, 11:30 am **Preserving the global effect across a saccade** Kiki Arkesteijn[1,2](k.arkesteijn@vu.nl), Jeroen B.J. Smeets[2], Mieke Donk[1], Artem V. Belopolsky[1]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit, Amsterdam, The Netherlands, [2]Department of Human Movement Sciences, Vrije Universiteit, Amsterdam, The Netherlands

When a distractor is presented in close spatial proximity to a target, a saccade tends to land in between the two objects rather than on the target. This ‘global effect’ is thought to reflect unresolved competition between target and distractor. It is unclear whether the global effect persists across saccades since a saccade displaces the retinotopic representations of target and distractor. In the present study participants performed a sequence of a horizontal and a vertical saccade and the global effect was induced by presenting a distractor next to the second saccade target. This distractor was removed during the first saccade. On half of the trials, the second target also disappeared after the first saccade, resulting in a memory-guided second saccade. On these trials, the second saccade showed a global effect, despite the disappearance of the distractor after the first saccade. Without correction based on a visible target location, the global effect was stable over hundreds of milliseconds. This suggests that the biased saccade plan was remapped across the first saccade. However, when the second target remained present after the first saccade, the bias was corrected and the global effect was eliminated, even for saccades with the shortest intersaccadic intervals.

32.25, 11:45 am **Presaccadic attention reshapes the sensory representation even when it impairs performance** Hsin-Hung Li[1](hsin.hung.li@nyu.edu), Jasmine Pan[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Goal When preparing a saccade, visual sensitivity at the saccade target is enhanced before saccade onset. This effect, presaccadic attention, might play a role similar to covert attention by prioritizing the target of interest and improving performance. Recently, we used psychophysical reverse correlation and found that presaccadic attention modulates feature representations by sharpening orientation tuning and shifting spatial frequency (SF) tuning toward higher SFs (Li, Barbot, Carrasco, Current Biology 2016). Here, we investigate whether this shift of SF tuning occurs even when it might be detrimental to the task at hand. Methods In an orientation discrimination task, the target (1 cpd grating oriented +/- 45° from vertical) was superimposed with masks of different SFs (0.67/1/1.5 cpd). The stimulus was presented 10° left or right from fixation. In the saccade condition, a precue instructed observers to saccade to the cued location. Shortly after the precue (12-224 ms), the stimulus flashed (35 ms) at the cued location, being presented presaccadically in most trials. In the neutral condition, the precue pointed to both locations and observers maintained fixation throughout the trial. We hypothesize that if presaccadic attention shifts SF tuning automatically, presaccadic attention will either improve or impair performance depending on the SF of the mask. Results Compared to the neutral condition, presaccadic attention improved performance (d') when the mask SF was the same or lower than the target, but impaired performance when the mask SF was higher than the target. In a control experiment with the same timing, covert attention did not affect performance. Conclusion Presaccadic attention shifts SF tuning toward higher SFs, even when it impairs performance for the task at hand. Besides prioritizing the saccade target, presaccadic attention reshapes its representation by enhancing resolution, possibly to mimic the post-saccadic representation of the saccade target.

Acknowledgement: H.-H.L. was supported by NIH Grant R90DA043849

32.26, 12:00 pm **Classification and Statistics of Gaze In World Events** Rakshit S Kothari[1](rsk3900@rit.edu), Zhizhuo Yang[1], Kamran Binaee[1], Reynold Bailey[1], Christopher Kanan[1], Jeff Pelz[1], Gabriel Diaz[1]; [1]Imaging Science, College of Science, Rochester Institute of Technology

It is known that the head and eyes function synergistically to collect task-relevant visual information needed to guide action. However, investigation of eye/head coordination has been difficult because most gaze event classifiers algorithmically define fixation as a period when the eye-in-head velocity signal is stable. However, when the head can move, fixations also arise from coordinated movements of the eyes and head, for example, through the vestibulo-ocular reflex. To identify fixations when the head is free requires that one accounts for head rotation. Our approach was to instrument multiple subjects' with a 6-axis Inertial Measurement Unit and a 120 Hz SMI ETG2 to record angular velocity of the eyes and head as they performed two tasks (ball catching & indoor walking) for 5 mins each. This yielded over 40 mins of gaze data. Four experts manually annotated a portion of the dataset as periods of gaze fixations (GF), gaze pursuits (GP), and gaze shifts (GS). Each data sample was labelled by the majority vote from the labelers. This dataset was then used to train a novel 2-stage Forward-Backward Recurrent Window (FBRW) classifier for automated event labelling. Inter-labeler reliability (Fleiss-kappa) was used to compare the performance of trained classifiers and human labelers. We found that 64 to 78 ms duration provides enough context for classification of samples with an accuracy above 99% on a subset of the labelled data that was not used during the training phase. In addition, analysis of Fleiss' kappa indicates that the algorithm classifies at rate on-par with human labelers. This algorithm provides new insight into the statistics of natural eye/head coordination. For example, preliminary statistics indicate that fixation occurs very rarely through stabilization of the eye-in-head vector alone, but through coordinated movements of the eyes and head with an average gain of 1.

Acknowledgement: Google

32.27, 12:15 pm **Pursuing an imaginary foveal stimulus increases catch-up saccades** Stephen Heinen[1](heinen@ski.org), Jeremy B Badler[1], Scott NJ Watamaniuk[1,2]; [1]The Smith-Kettlewell Eye Research Institute, [2]Wright State University

Catch-up saccades during pursuit are thought to result from excessive position or velocity error. However, despite similar errors, a large pursuit target with an embedded foveal spot elicits more catch-up saccades than the large target alone. Furthermore, attending the embedded spot elicits more catch-up saccades than attending the large target. Here we ask if the higher frequency of catch-up saccades when attending the spot was mediated by the position error to the foveal target, or if attention at the fovea alone is sufficient to amplify the contribution of the saccadic mechanism. Observers pursued a stimulus composed of a 6° circular array of eight dots that traversed the screen at 10 deg/sec. In one condition, they detected a near-threshold luminance increase at a randomly selected peripheral dot that occurred at a random time on 50% of trials. In a second condition, observers detected a near-threshold stimulus that appeared in the center with the same frequency as the peripheral luminance change. An EyeLink 1000 recorded eye movements at 1000 Hz. We found that the catch-up saccade rate was higher when observers attended the center, even during epochs when no stimulus was present. Thus, foveating an imaginary stimulus still engaged the saccadic system. The results suggest that the frequency of catch-up saccades during pursuit in the absence of a foveal stimulus can reveal if attention is at the fovea. Furthermore, we find a similar result in our fixation data, evidence for a common mechanism subserving catch-up and micro saccades.

Acknowledgement: NEI-1R01EY021286

Sunday Morning Posters

Scene Perception: Objects, search, complexity

Sunday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

33.301 **How difficult is it to identify a watermelon in a basketball court? Explaining the difficulty to identify incongruent objects** Liad Mudrik[1, 2](liadmu@gmail.com), Alyssa Truman[2], Ran Amram[1]; [1]School of Psychological Sciences, Tel-Aviv University, [2]Sagol School for Neuroscience, Tel-Aviv University

Objects in the real world do not appear in a void. Rather, they are typically found within a broader context, having relationships with the environment. Numerous studies have shown that these relationships affect subjects' performance, so that incongruent objects (i.e., objects that appear in unexpected scenes) are typically identified less accurately and slower than congruent objects. Yet an ongoing debate involves the source of this effect, and its prerequisites: does it stem from a genuine difficulty to identify incongruent objects, or does it reflect a later, post-perceptual process? And does it depend on explicit congruency detection or on conscious perception? Here, we present results from three EEG experiments; the first focuses on the N300 component, held to reflect object identification processes. By presenting congruent/incongruent objects that are either intact or scrambled, we show that the congruency-evoked N300 is different from identifiability–evoked N300, yet we still find a later divergence of waveforms evoked by intact incongruent objects from scrambled ones (as compared with the divergence of congruent intact and scrambled objects), providing first direct evidence for the difficulty to identify incongruent objects. We then focus on the scene-N400 component, held to index integration attempts between the object and the scene, and show that it is modulated both by explicit vs. implicit detection of scene incongruency (Exp. 2), and by conscious vs. unconscious processing of the scene (Exp. 3).

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33.302 **Salience-based object prioritization during natural-scene viewing in elderly and young adults** Immo Schuetz[1](schuetz.immo@gmail.com), Wolfgang Einhäuser[1], Antje Nuthmann[2,3]; [1]Institute of Physics, Chemnitz University of Technology, Germany, [2]School of Philosophy, Psychology and Language Sciences, University of Edinburgh, United Kingdom, [3]Institute of Psychology, University of Kiel, Germany

There is an ongoing debate whether gaze in natural scene viewing is primarily guided by image salience or by high-level scene content, such as objects. Put to the extreme, in a „salience view" fixations are exclusively guided by low-level image features. In contrast, the „object view" stipulates that objects drive fixations. In this view, any relation between low-level features and fixations is epiphenomenal. A recent study found salience effects to decrease with age. However, the question of object-based fixation guidance has not been investigated in the elderly. To fill this gap, we investigated object-based fixation guidance in images of natural scenes for young (N=42; 18-29 years) and elderly (N=34; 66-83 years) observers. We used an analysis framework based on Generalized Linear Mixed Models (GLMMs). The GLMMs quantified the unique contributions of object salience, object size, and distance between object and scene center. Salient objects were fixated with higher probability than less salient objects. This effect was stronger in the group of elderly observers. In contrast, when analyzing fixation guidance independent of objects, salience effects were weaker in the elderly, replicating earlier findings. Our results reconcile the two views: fixation guidance has a strong object-based component, but objects are prioritized based on salience. Object-based and object-independent salience exhibit distinct patterns for the two age groups: object-independent salience is stronger in young than in old observers, while salience-based object prioritization is stronger in the elderly. We interpret these findings as an increase of object-related attention guidance with age.

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33.303 **Contextual effects of coarse global scene properties on object processing** Tim Lauer[1](tlauer@psych.uni-frankfurt.de), Verena Willenbockel[1], Julia I. Kunz[1], Melissa L.-H. Võ[1]; [1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, Germany

Objects that are semantically related to their scene context are better recognized than objects shown in unrelated surroundings. While this object-scene consistency effect has been reported many times, it remains unclear which information of a scene is used to facilitate semantic object processing. Here, we specifically investigated whether coarse global scene properties preserved by low spatial frequencies (SFs) – that have been shown to mediate a scene's "gist" – drive the consistency effect. In two experiments, we manipulated semantic object-scene consistency by presenting indoor or outdoor objects superimposed on indoor or outdoor scenes. On each trial, a consistent or inconsistent object-scene pair was displayed for 50 ms followed by a dynamic mask. Observers' task was to name the foreground object as precisely as possible, and afterwards report how confident they were about their answer. In Experiment 1, the background scenes were either unaltered, low-pass filtered at 8 cycles per image (cpi) – corresponding to 0.31 cycles per degree of visual angle (cpd) – or scrambled by randomly re-arranging all pixels. In Experiment 2, the scenes were either presented unaltered, low-pass filtered with a higher cutoff (17 cpi; 0.66 cpd) or as hybrid images, selectively preserving the SFs found to be diagnostic for rapid basic-level scene categorization (Willenbockel, Gosselin, & Võ, VSS 2017). In both experiments, in the unaltered scene condition, participants named consistent objects more accurately than inconsistent objects, whereas no such consistency effect was found for any other condition. The confidence ratings were unaffected by the consistency manipulation across conditions. Thus, while low SFs mediate scene gist, we have found no indication that these low SFs have behavioral effects on object processing. Recording event-related potentials might provide an alternative, possibly more sensitive, approach to assess the contribution of coarse global scene properties to the object-scene consistency effect.

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33.304 **Automaticity of scene understanding may not extend to highly associated actions or objects** Sara Spotorno[1,2](sara.spotorno@glasgow.ac.uk), Philippe G. Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, [2]School of Psychology, University of Aberdeen

The rich literature on scene understanding has shown that human observers may quickly extract and represent several types of high-level information when viewing a scene. It has been suggested that the category of a scene is automatically accessed during viewing, but no previous studies have examined whether other types of knowledge concerning the scene are accessed in an automatic fashion as well. In this study, we examined whether such automaticity exists for actions and objects that are highly associated with the scene's schema. We used a lexical-decision task combined with a picture-word interference paradigm, in which participants had to decide whether a string of letters presented on a scene image was a word or a pseudoword. Words were scene, action and object labels, highly associated or weakly associated with the image. We manipulated task difficulty by varying the similarity between the pseudowords and the words from which they were derived. The stimuli were presented until response. We found slower response times in the weakly versus highly associated condition only for scene labels. Moreover, this interference effect was independent of label's length and of task difficulty. This shows that it was not modulated by cognitive load and available attentional resources. Our results suggest that automaticity of knowledge access may

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be restricted to the category of the scene when primed by the precise scene label, without embracing other components of the scene's schema, which might therefore be inferred as a second processing step during scene understanding.

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33.305 **Anchoring spatial predictions in real-world scenes: Hierarchical relationships of objects predict single trial search performance** Melissa LH Võ[1] (mlvo@psych.uni-frankfurt.de), Sage EP Boettcher[2], Dejan Draschkow[1]; [1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, [2]Department of Experimental Psychology, University of Oxford

General scene knowledge (our "scene grammar") plays an important role in both identifying and locating objects in the real world. This knowledge reflects co-occurrences of scene elements and their structural regularities. Some objects appear more frequently within a specific context, e.g. a toothbrush in a bathroom rather than in a bedroom. When trying to locate an object, however, predicting the spatial relationship between various objects within a single scene is key for efficient search performance. We propose that the arrangement of objects is not only rule-governed, but hierarchical in its structure. In particular, we believe that some objects within each scene category function as anchors, carrying strong spatial predictions regarding other objects within the scene (e.g. the stove anchors the position of the pot). Therefore, these "anchors" constitute key elements in the hierarchy of objects in scenes. To test this hypothesis and to quantify the spatial relationship between objects in different scene categories, we extracted the spatial locations of objects from an image database. Inspired by graph theory, we captured the relationship of objects as a set of nodes connected by edges of varying weights. As a first approximation, our weights were set by 1) the general frequency of an object to object pairing, 2) the mean distance between these objects across many instances of a scene category, as well as 3) the standard deviation in the horizontal relationship between the objects (above/below). Stronger weights indicate a stronger spatial relationship between two objects. Based on these weights combined with cluster analyses, we identified "anchor" objects. We tested the behavioral relevance of the weight parameters by correlating them with search performance. Results show that reaction time decreases as weights increase. We take this as evidence that anchors predict single trial search performance for other objects in naturalistic scenes.

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33.306 **Was that a moose on the road? Gist-like perception of emerging driving hazards** Benjamin A Wolfe[1](bwolfe@mit.edu), Ruth Rosenholtz[2]; [1]CSAIL, Massachusetts Institute of Technology, [2]Brain and Cognitive Sciences, Massachusetts Institute of Technology

Recent work on perceiving the gist of a static image, whether a natural scene or a radiological scan, has shown that the visual system extracts details quickly, allowing for rapid discrimination and identification. While these findings are well-established in vision research, they have yet to penetrate to driving, where drivers are thought to take seconds to process the road scene. To test whether subjects could perceive the gist of a road scene, we performed two experiments where they were asked to discriminate between normal driving video and video showing pre-collision cues. In our first experiment, subjects viewed short clips (100 - 1000 ms duration) and were asked to discriminate pre-collision from normal driving scenes. Subjects were able to discriminate the scenes above chance at all durations, and performance plateaued beyond 300-400 ms. Using these results, we also investigated variability in rapid discrimination of driving environment as a function of position in the visual field. Subjects fixated one of five locations (ranging 20-30º from road center) and performed the same task as before, with a fixed video duration of 300 ms. Subjects remain capable of this discrimination when the roadway is in peripheral, rather than central vision, although we find a small decrease in sensitivity. Subjects' ability to perform this task suggests that the visual system is not only processing the moving scene in the time available, but successfully detecting a wide variety of potentially hazardous deviations from what would be normal in the scene. Understanding what drivers can and cannot perceive quickly is particularly timely given the advent of automated vehicles; drivers may not need to attend to the road all of the time, but must return attention to the road and rapidly acquire gist at a moment's notice.

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33.307 **Across the planes: Differing impacts of foreground and background information on visual search in scenes** Louisa LY Man[1](12LLYM@queensu.ca), Monica S Castelhano[1]; [1]Department of Psychology, Queen's University

When searching in real world scenes, our visual system needs to efficiently sift through complex visual information to quickly find the target. One prevailing question is how the visual system prioritizes and processes information to perform tasks effectively. Researchers have postulated that scene representations consist of both background and foreground elements, where background elements provide a scaffold for more detailed foreground elements (Davenport & Potter, 2004; Henderson & Hollingworth, 1999; Munneke, Brentari & Peelen, 2013). Here, we defined background information as boundary defining elements such as walls, floors, ceilings (Oliva & Torralba, 2001) and foreground information as moveable objects nested inside the background (Henderson & Hollingworth, 1999). In the current study, we were interested in how scene information from different planes impacts search for targets (foreground versus background). We introduced a new stimulus set: chimera scenes, which have the foreground set of objects belonging to one scene category, and the surrounding background structure belonging to another. We posit that differences in how the background and foreground are processed will result in different search strategies across scene planes. Participants performed search in scenes that had either consistent (Normal) or inconsistent (Chimera) foreground and background contexts. Target objects could appear in either the foreground or background of the scene. Results showed an interesting effect of target placement. Although participants had a longer target latency for foreground than background targets, they had a shorter response times, had fewer fixations to the target, and had a more direct scan path to the target when the target was in the foreground. Moreover, participants were able to discern foreground targets from farther in the periphery than background targets. These results suggest that there are processing differences between searches for target in different planes of the scene. Implications for scene representations and search mechanisms will be discussed.

Acknowledgement: NSERC

33.308 **Perceived Complexity and Aesthetic Responses to Landscape Photographs** Whitney M Tate[1], Richard P Taylor[2], Margaret E Sereno[3], Alexander J Bies[1]; [1]Psychology, College of Behavioral and Health Sciences, Middle Tennessee State University, [2]Physics, College of Arts and Sciences, University of Oregon, [3]Psychology, College of Arts and Sciences, University of Oregon

Models of aesthetic experience suggest cognitive processes including complexity perception are involved in forming aesthetic responses (essentially, the appreciation of beauty). Investigating the relationship between the constructs perceived complexity and aesthetic value allows us to better understand the relationship between cognitive processes that contribute to aesthetic responses and outcomes of that evaluative process. The present study aims to understand the relationship between perceived complexity and aesthetic responses. Twenty participants (13 female) were shown instructions indicating they would rate a series of images on a continuous scale from 0 (lowest) to 1 (highest) by clicking on a scale bar, and instructed to try to use the full range of the scale (not binary 0 or 1 responses) across trials. Each participant was then told the quality on which they should rate the images – a facet of complexity ("complexity" or "simplicity") or aesthetic value ("attractiveness" or "beauty"). Participants then rated each image sequentially, with image order randomized for each person. The images were a set of 200 black and white landscape photographs, taken with an AF-S DX NIKKOR 10-24mm lens set to 24mm affixed to a Nikon D7100 camera. Confirmatory factor analyses, in which each participant served as an "item" in a factor analysis where images were the "subjects," revealed that participants who rated the same property (e.g., simplicity) loaded on a single factor. We then analyzed the relationship between four pairs of complexity and aesthetic factors (e.g., "simplicity" and "attractiveness"), three of which provided a good fit with high factor loadings. The strong relationship between the latent constructs

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extracted from participants' responses indicates these are tightly coupled concepts. This suggests that for black and white photographs of landscapes, perceived complexity is largely sufficient to drive aesthetic responses, and that other theoretical paths are unnecessary.

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33.309 **A factor analytic approach reveals variability and consistency in perceived complexity ratings of landscape photographs** Alexander J Bies[1](alexander.bies@mtsu.edu), Whitney Tate[1], Richard P Taylor[2], Margaret E Sereno[3]; [1]Psychology, College of Behavioral and Health Sciences, Middle Tennessee State University, [2]Physics, College of Arts and Sciences, University of Oregon, [3]Psychology, College of Arts and Sciences, University of Oregon

We engage with novel scenes' complexity until we achieve recognition and comprehension, which is important for activities from object identification to aesthetic evaluation. The physical complexity of a scene can be described in a multitude of ways, but a lack of individual differences studies implies our field holds the assumption that complexity perception is a basic perceptual process, consistent across individuals. Here, we take an unconventional approach to factor analysis to answer the question of how universal or idiosyncratic individuals' perceptions of complexity really are. Twenty-five participants (16 females) rated 200 landscape photographs. Each participant rated all of the images on a particular quality that relates to complexity (e.g., intricacy or simplicity). Correlation matrix heatmaps revealed variability across individuals, with most individuals' ratings exhibiting correlations of moderate strength with respect to others' ratings. Confirmatory factor analyses revealed that, for most participants, sets of five individuals who rated a given quality (e.g., intricacy) showed fairly strong agreement with others who rated the same quality (as indicated by strong loadings and non-significant chi-square tests). With regard to the relationship between factors, some models were good fits and revealed strong relationships between latent constructs, while others did not. Similarly, poor fits were observed for confirmatory factor analyses that sampled from each rated quality group (i.e., one participant who rated intricacy, another who rated simplicity, etc.). Thus, perceived complexity appears to be a multifaceted construct that could support individual differences, depending upon the aspects of a scene to which an individual is attending. In addition to supporting the study of scene complexity, the factor analytic approach we took here can be applied broadly to other studies with large numbers of stimuli. Importantly, this allows for particular responses to be correlated, which provides insights into the cognitive processes involved in responding to the presented images.

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33.310 **Picture Perception Reveals Rules of 3D Scene Inference** Erin M Koch[1](ekoch@sunyopt.edu), Famya Baig[1], Qasim Zaidi[1]; [1]Graduate Center for Vision Research, College of Optometry, State University of New York

How do we infer 3D scene layout from a retinal image without using stereo disparity? We created a scene of two bodies on a ground plane with limbs at different angles, and simpler spatial configurations of rectangular bricks. Images of the scenes were acquired from different camera angles, and each was seen on a large monitor from 5 viewpoints. Observers rotated vectors on a horizontal touch screen to match 3D limb/brick orientations. The perspective projections of 3D orientations form a trigonometric function, that we inverted to derive the back projection for perfectly inferring 3D orientations from retinal images. Inferences about a real scene through a window were simulated by the screen being fronto-parallel to the observer's eyes. Observers' 3D orientation judgments corresponded to a shallower version of the perfect back-projection, suggesting a heavy reliance on 2D retinal orientations, but with a fronto-parallel bias for oblique 3D orientations. Adding one multiplicative parameter to the mathematical back projection, successfully fit the 3D percepts as a function of 2D retinal orientation ($R2 = 0.94 – 0.99$ across 10 observers). Analyzing 3-D orientation inferences from oblique views of the 2D images, we found that observers used the same rules, but with the assumption that the back-projection function applied to observer centered coordinates causing the 3-D scene to be perceived as rotated towards the observer. A fixed rotation equal to viewing angle, applied to the best fitting function from the fronto-parallel view, successfully fit the average results for oblique viewpoints ($R2 = 0.98 – 0.99$). The invariance of vertical retinal orientations across viewpoints, explained why the same limbs/bricks were perceived as pointing towards the observer in all views. Since observers seem to use the same inferential rules regardless of viewpoint and perceptual veridicality, we suggest that these rules are used for 3-D perception of real scenes.

Acknowledgement: EY013312

Object Recognition: Categories

Sunday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

33.311 **Bottom-up processing of intermediate visual features is sufficient for animate/inanimate object categorization.** Amanda C. Del Giacco[1](amanda.delgiacco@nih.gov), Valentinos Zachariou[1], Leslie G. Ungerleider[1], Xiaomin Yue[1]; [1]Laboratory of Brain & Cognition, NIMH, Bethesda, MD

Animate and inanimate objects differ in their intermediate visual features. For instance, animate objects tend to be more curvilinear compared to inanimate objects (Levin et al. 2001; Perrinet and Bednar, 2015; Long et al. 2016). Recently, it has been demonstrated that these quantitative differences in the intermediate visual features of animate and inanimate objects are sufficient for categorization: human participants can classify synthesized images of animate and inanimate objects that differ largely in the amount of these visual features significantly above chance (Long et al. 2016). A remaining question, however, is whether this observed categorization is a consequence of simple, top-down cognitive strategies (e.g. rectangular shapes are less likely to be animals) or a consequence of bottom-up processing of their intermediate visual features, per se, in the absence of top-down cognitive strategies. To discriminate between these two alternatives, we repeated the classification portion of Long et al. (2016) but matched the synthesized stimuli, on average, in the amount of image-based and perceived curvilinear and rectilinear information. Additionally, in our synthesized stimuli, global shape information was not preserved and the images appeared as texture patterns. These changes prevented participants from using top-down cognitive strategies to perform the task. We found that participants (n=20) still classified these synthesized stimuli significantly above chance, even though they were unaware of their classification performance. For both object categories, participants used the curvilinear, but not the rectilinear image-based information present in the stimuli for classification. The perceived measures of curvilinearity and rectilinearity did not predict classification performance. Surprisingly, the stimuli most consistently classified as animate corresponded to the most dangerous animals in our sample of images. We conclude that bottom-up processing of the curvilinear features present in the visual input conveys information associated with the valance/arousal of the stimuli and is sufficient for animate/inanimate object categorization.

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33.312 **Prefrontal and category-selective ventro-temporal regions exhibit differential interactions between stimulus visibility and task** Lior Bugatus[1,2](liorbu@stanford.edu), Kalanit Grill-Spector[1,2]; [1]Department of Psychology, Stanford University, Stanford, CA, [2]Stanford Neuroscience Institute, Stanford University, Stanford, CA

How do task relevance and stimulus visibility affect responses to visual categories in human ventral temporal cortex (VTC) and ventro-lateral prefrontal cortex (VLPFC)? We addressed this question by conducting 2 fMRI studies in 5 participants who viewed stimuli from three visual categories (faces, cars, and houses), at three visibility levels (low: 20% opacity, mid: 25% opacity, and high: 50% opacity), while performing either an exemplar or a fixation task. In the exemplar task, subjects were cued to detect a particular exemplar (occurring 0-4 times within a block of 12 images from a category). In the fixation task, subjects viewed the same stimuli, but were cued to detect a fixation color (occurring 0-4 times in a block). Subjects also participated in a whole brain anatomical scan as well as a localizer used to define regions of interest (ROIs) selective to faces and places. Results reveal that face and place-selective ROIs in VTC exhibited

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an interaction between task and visibility: In the exemplar task, response amplitudes were similar across the three visibility levels, but during the fixation task responses increased with visibility level, particularly for the preferred stimulus. These data suggest that in VTC, top-down attention to an exemplar can override the effects of bottom-up stimulus visibility. In contrast, in the VLPFC, inferior frontal junction (IFJ) exhibited an opposite pattern of response: In the exemplar task, responses to visual categories in IFJ decreased with increased visibility, but during the fixation task, responses were similar across visibility levels and were indistinguishable from baseline. These data suggest that IFJ responses are modulated by both task relevancy and difficulty. Together these data suggest that top-down influences from prefrontal regions onto category-selective ventral-temporal regions enhance the latter's response during low visibility conditions only when these are task relevant.

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33.313 **Changes in Visual Scanning Strategies Accompany the Acquisition of Perceptual Expertise** Allison N Carr[1](acarr5@ufl.edu), Andrea Cataldo[2], Hillary Hadley[2], Erik Arnold[2], James Tanaka[3], Tim Curran[4], Lisa S Scott[1]; [1]Department of Psychology, University of Florida, [2]Department of Psychological and Brain Science, University of Massechusetts Amherst, [3]Department of Psychology, University of Victoria, [4]Department of Psychology & Neuroscience, University of Colorado Boulder

Perceptual expertise is described as the improved ability to recognize, identify, and discriminate between items within a domain of expertise. Past work on perceptual expertise suggests that subordinate-level training, but not basic-level training or exposure, leads to increased discrimination of birds and cars (Scott et al., 2006; 2008). However, it is unclear whether improvements in discrimination associated with increased perceptual expertise are accompanied by changes in visual strategies. Adults (n= 28) were trained to discriminate between "species" of novel computer-generated objects (Figure 1). Stimuli included two separate families of objects, each with 10 unique species. Within subjects, participants were trained (9 hours of training across a 2-3 week period) to discriminate one family at the subordinate level and the other at the basic level. Eye-tracking and accuracy (d') during a serial image matching task were assessed pre- and post-training. The ScanMatch Matlab Toolbox (Cristino et al., 2010) was used to further examine visual fixations by placing a grid over the image and coding the temporal and spatial sequences of fixations. Similarity scores were calculated within particpants for each condition and at pre- and post-test. Consistent with past perceptual expertise training studies (Scott et al., 2006; 2008), there was an increase in accuracy for the serial image matching task from pre-test to post-test, for the subordinate ($p < .001$), but not the basic trained family. For eye-tracking, there was no change in dwell time from pre- to post-test or between basic or subordinate level training. Scan path analyses suggest that consistent fixation patterns emerge within participants after subordinate-level training ($p < .001$), but not basic-level training (Figure 2). These results indicate that, unlike overall dwell time, changes in visual fixation patterns after subordinate-level training are consistent with increased discrimination and may be an important index of perceptual expertise.

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33.315 **Gist Perception and Holistic Processing in Rapidly Presented Mammograms.** Michael D Chin[1](michaelchin45@gmail.com), Karla K Evans[2], Jeremy M Wolfe[3], Jim W Tanaka[1]; [1]University of Victoria , [2]University of York, [3]Harvard Medical School

The "gist" perception required for radiology diagnosis resembles the non-analytic, holistic processing that is often associated with face recognition. In a previous study, we (Chin, Tanaka, Evans & Wolfe) tested the holistic perception of mammograms using an inversion task in a mixed design of upright and inverted faces. Experienced (> 5 years of experience) but not residents (< 5 years of experience) demonstrated an inversion effect for bilateral mammograms presented at 1000ms, suggesting that holistic perception develops over time and with training. However, the relationship between "gist" and holistic processing remains unclear given the long exposure of this experiment (1000ms). In the current experiment, we employed both brief (250 ms) and longer (1000 ms) exposure durations blocked by orientation (upright, inverted). Twenty-one expert radiologists and residents made "normal" or "abnormal" discriminations of upright or inverted craniocaudal single breast mammograms; half of the images were "normal" and half of the images contained subtle cancerous abnormalities. Results seem to show an interaction between radiology experience, presentation time and image orientation. All radiologists performed well above chance in the 250ms condition and showed equal discrimination performance for upright and inverted mammograms. This is consistent with the evidence in radiology that global gist processing is not strongly dependent on structure. In the 1000ms condition, the more experienced radiologists demonstrated a significant increase in overall performance and demonstrated a reliable inversion effect. We suggest that the increased discrimination in the 1000 ms condition was due to sensitivity to orientation-dependent structural information in the mammogram that is acquired with expertise.

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33.316 **A large-scale object database based on representative sampling of the English language** Adam H Dickter[1](adam.dickter@nih.gov), Martin N Hebart[1], Alexis M Kidder[1], Wan Y Kwok[1], Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health

As vision scientists, we are interested in understanding how humans and other animals process visually-presented objects. Selecting object stimuli and categories for probing object processing has remained challenging, for at least two reasons. First, small stimulus sets may suffer from selection bias, while large-scale stimulus sets may over-represent objects common in the stimulus pool. Second, selecting objects requires deciding the level of categorization for each object (e.g. "cod" or "fish"), which may or may not be relevant to the observer. To address these issues, we developed a large-scale database of objects in natural context, based on a list of 40,000 generally known English word lemmas (Brysbaert et al., 2014). From this list, we selected all nouns that were rated as concrete, that could be depicted, and that were not scenes. After carrying out word-sense disambiguation using WordNet, we determined the relevance of each object label to human observers. To this end, we selected one object image per label from Google and asked Amazon Mechanical Turk workers to label each object. After exclusion of objects that were rated highly inconsistently or provided a more general level of description (e.g. a picture of a "cod" called "fish"), this left us with a set of 1,850 object categories. We rank ordered each category based on a combination of word frequency and concreteness. For the selection of object images, we crawled Google Images, Flickr, and Imagenet based on manual screening of images (Mehrer et al., 2017). From those images, we manually selected a minimum of 12 object images per category, with natural background and cropped to square size for better comparability. The complete set of more than 24,000 object images, together with the rank ordering of categories, provides a novel resource for the study of object processing.

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33.317 **Human Object Detection in Natural Scenes: Evidence From a New Dot Probe Task** Colin S Flowers[1](cflowers@email.arizona.edu), Mary A Peterson[1,2]; [1]Department of Psychology, University of Arizona, [2]Cognitive Science Program, University of Arizona

Object detection is often measured by assessing whether an object of a given category was present in a briefly exposed scene. With this task, some accurate responses might be based upon scene context. Here, we measure object detection by instructing participants (n = 53) to report whether a colored flashing dot probe located near a border in a colored photograph of a natural scene was "on" or "off" the object bounded by that border (100-ms masked exposure). Dot location varied from central to peripheral regions of the photographs. Accurate responses were taken to index accurate object detection. This method reveals object location rather than category. We investigated category effects by presenting 741 photographs from the Common Objects in Context (CoCo) set containing objects in 10 different categories (54 – 89 objects per category). Overall accuracy was 65.34%. A one-way ANOVA showed a significant effect of category ($p < 0.001$). Performance was poorest (although significantly greater than

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chance) on small textureless objects (e.g. knives/forks; 57.11%), or objects that were often occluded in the photographs (e.g., bowls/cars; 58.26%). These objects often caused computer vision models of object detection to fail. Detection accuracy for these objects was significantly lower than all other categories, ps < 0.04. Performance was best on textured objects that were generally the focal point of the photographs (e.g., airplanes/birds/zebras - 74.61%, were detected significantly better than objects in all other categories, ps < 0.03), objects that are often accurately detected by computer vision models. Performance with the objects in the other categories (apples/chairs/people) was intermediate. Our method, emphasizing locating objects within scenes, provides evidence regarding human object detection while eliminating guessing based on context. We plan to use black and white photographs to increase the visibility of the colored flashing dot probe to determine whether this pattern remains unchanged.

Acknowledgement: ONR N00014-14-1-067

33.318 **Examining within-category discrimination of faces and objects of expertise.** Simen Hagen[1](shagen@uvic.ca), James W. Tanaka[1]; [1]Department of Psychology, University of Victoria

Object experts quickly and accurately discriminate objects within their domain of expertise. The current study used a novel and implicit visual discrimination paradigm coupled with electroencephalography – Fast Periodic Visual Stimulation – to examine whether within-category discrimination of face and non-face objects of expertise rely on shared visual discrimination mechanisms. Bird experts and novices were presented with sequences of the same object image of a family-level bird (Robin), species-level bird (Purple Finch), or face (Face A) at a periodic rate of six images per second (6.00 Hz), with size varying randomly at every cycle to restrict adaptation to areas sensitive to object discrimination. A different within-category "oddball" family-level bird (Finch), species-level bird (Cassin's Finch) or face (Face B) was interleaved with the base image at every 5th cycle (1.20 Hz). Thus, a differential response at 1.20 Hz is an index of within-category discriminability between the base- and oddball-objects. We reasoned that discriminability of one object domain should be correlated at the participant level with the discriminability of another object domain if they share common visual discrimination mechanisms. The results showed a robust base signal (6.00 Hz, medial-occipital channels) and discrimination signal (1.20 Hz, occipito-to-temporal channels) that did not differ as a function of group by object domain. At the participant level, the base signal (6.00 Hz, medial-occipital channels) for all object categories positively correlated in both experts and novices. Importantly, the discrimination signal (1.20 Hz, occipito-temporal channels) for face and birds correlated in experts, but no pattern of correlations was found in novices. Moreover, family- and species-level birds correlated in both experts and novices. This indicates that the discrimination mechanisms for faces and birds were shared in the experts, but not in the novices. Overall, this suggests that face and non-face objects of expertise share visual discrimination mechanisms.

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33.319 **The effect of task on categorization behavior and its relationship to brain and deep neural networks** Martin N Hebart[1](martin.hebart@nih.gov), Charles Y Zheng[2], Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, [2]SFIM Machine Learning Core, National Institute of Mental Health

A key objective in neuroscience is to understand how brains produce behavior. For the visual processing of objects, one approach is to relate categorization behavior to object representations at different cortical processing stages. A popular method to assess behavior is the object arrangement task, in which participants arrange objects in a 2D "arena" based on their relative similarity. While this method is efficient in producing representational dissimilarity matrices (RDMs) and is well-suited for uncovering low-dimensional representations or clearly defined clusters, it is prone to contextual biases and may be suboptimal for higher-dimensional or more continuous representations. Here we investigate the triplet task as an alternative approach for studying behavioral similarity. In this task, on each trial a participant has to choose an "odd-one out" from a set of three stimuli, yielding three binary similarity measures per response. For small to intermediate RDMs, this approach is efficient and cheap when carried out online in a distributed fashion, quickly yielding responses from hundreds of participants, while minimizing contextual effects. We compared RDMs obtained from both tasks using a set of 48 representative objects and tested their correspondence to deep neural networks (DNNs) that exhibit human-like categorization performance. While the RDMs between both tasks were highly correlated, the triplet RDM correlated much more strongly with DNN layers than the arrangement task. Using a commonly studied, more structured set of 92 objects, our results revealed comparable relationship to DNNs. However, the triplet task outperformed the arrangement task in explaining responses in human IT and later MEG responses, while earliest MEG responses were dominated by the arrangement task. Together, these results reveal the importance of the behavioral metric in teasing apart the relationship between brain, DNNs, and behavior. Further, our method provides a novel, efficient approach for obtaining behavioral measures of similarity.

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33.320 **Categorical Targets Can Be Identified without Localization** Shekoofeh Hedayati[1](suh437@psu.edu), Brad Wyble[1]; [1]Pennsylvania State University (Psychology Department)

The binding problem in visual perception refers to linking features (e.g. color, shape, size, location) of a particular object to perceive it as a unified object. In this research we attempted to examine the binding mechanism underpinning location and identity in a categorical search. In a visual search task for features by Treisman and Gelade (1980), identity and location report were not tightly linked, such that one could report the identity but not the location of a target and vice versa. However, Johnston and Pashler (1990) reached a different conclusion by correcting for various kinds of errors and biases. They found that the detection of identity is highly contingent upon the correct detection of a feature's location and vice versa. It is not clear if similar effects would be obtained for targets specified at a more abstract, categorical level, such as letters among digits. Our prediction, based on findings of location-specificity in anterior portions of the ventral stream is that subjects would always have at least a general idea of the target's location if they could identify it. We used a categorical search paradigm in which five digits (distractors) and a letter (target) were presented simultaneously on the circumference of a hypothetical circle. Stimuli were presented for 50ms and then masked. Participants were asked to report the identity and the location of the letter on each trial. Contrary to our prediction, on trials in which the identity was reported correctly (chance was 3%) subjects were unable to report the general location (+/- one position around the hexagon, which was ½ of the positions) on 25% of trials. The results suggest that it is possible to detect categorical targets without being aware of their location. However, we did not find strong evidence that location can be reported without identity.

33.321 **Automatic categorical abstraction during visual statistical learning in children and adults** Yaelan Jung[1](jung.yaelan@gmail.com), Dirk B. Walther[1], Amy S. Finn[1]; [1]University of Toronto

One of the primary goals of the visual system is to make predictions about upcoming sensory events, which requires extracting and learning regularities from the environment. Research on visual statistical learning demonstrated that humans can not only learn these regularities from very brief exposure (Fisher & Aslin, 2001), but that this learning can occur at the categorical level; when images are always different, but regularities are present across categories (Brady & Oliva, 2008). In the present set of studies, we ask whether this category-level generalization of learning occurs even with exposure to repeated items. Additionally, we ask whether children learn categorical-level regularities like adults. Given evidence that children are more sensitive to features of individual items than adults (Sloutsky & Fisher, 2004) they may or may not show learning of regularities at the category level. We tested this question by performing several statistical learning experiments with adults (18-22 yo) and children (6-9 yo). Participants were exposed to a stream of animal images, which consisted of four sets of triplets, randomly distributed. Each triplet consisted of three animals appearing in the same order. Critically, the images were always novel exemplars from a given category. Observers

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were tested using a 2AFC Familiarity Judgment task between triplets of images, which either maintained or violated the temporal predictability from the exposure phase. We observed that adults and children showed familiarity to triplets in the exposed sequence, which suggests that they learned the regularities at the category level. To determine whether this categorical abstraction is automatic, we exposed children and adults to an image stream with regularities at the item level and tested with multiple novel exemplars. We found that both adults and children could still learn the statistical regularities at the category level even with single item exposure, suggesting that they can generalize item-level learning to categories.

33.322 **Drawings as a window into the development of object category representations** Bria L. Long[1](bria@stanford.edu), Judith Fan[1], Michael C. Frank[1]; [1]Department of Psychology, Stanford University

Drawing is a powerful tool for communicating concepts in visual form — a few well-placed strokes can convey the identity of a person, object, or scene. Prior work has found that deep neural network models of the ventral stream trained purely on photographs can also recognize drawings by nonexpert adults, reflecting concordance in abstract representations of object categories in drawings and photos at higher layers in these models (Fan, Yamins, & Turk-Browne, 2015). How do ordinary people become so effective at producing recognizable drawings? Here we examine the trajectory of this learning during childhood. Children (N = 41, M = 6.9 years, range 4-10 years) participated in an iPad-based drawing game where they were prompted with a verbal cue to draw one of sixteen familiar objects (e.g., "Can you draw a cup?"). Children drew each object category for 30 seconds, after which they were prompted to either make another drawing or to stop drawing altogether. Afterwards, a group of naive adults (N = 14) guessed the identity of each drawn object (286 drawings). A generalized logistic mixed-effect model revealed that the recognizability of drawings increased reliably with age (b = 0.96, SE = 0.17, Z = 5.5), accounting for variation across object categories and individual children (% drawings recognized; chance = 4.8%; M4yrs = 14%, M5yrs = 45%, M6yrs = 70%, M7yrs = 72%, M8yrs = 66%, M9yrs = 76%, M10yrs = 85%). Further, this relationship persisted when controlling for several low-level covariates — the amount of time spent drawing, the number of strokes, and total ink used. These results suggest that the capacity to quickly produce graphical representations that communicate object category information is highly developed by middle childhood. More broadly, these findings point to visual production tasks as a promising avenue for examining the development of object category representations.

33.323 **Using frequency tagging to study the effect of category learning on visual attention to object parts** Yue Meng[1](mengyue0903@gmail.com), Jonathan R Folstein[1]; [1]Psychology department, Florida State University

Subordinate-level category learning is known to cause perceptual improvements for learned stimuli outside of the category learning task. These improvements could be caused by improvements in visual attention or improvements in the feed-forward visual signal. Category learning tasks can cause changes in allocation of visual attention, specifically the ability to select diagnostic features in learned stimuli. On the other hand, object-based attention predicts that attention automatically spreads onto the whole object. Here we used frequency-tagging to examine how visual attention changes after training on categorization. Participants were trained over six sessions to categorize cartoon space plant stimuli based on 3 out of 6 features. In the following Steady-state EEG session, diagnostic features and nondiagnostic features were frequency-tagged. In each trial, participants were cued to monitor either diagnostic features or nondiagnostic features of an exemplar to detect the onset of a small red dot, they performed the same task on another set of untrained stimuli as well. Finally, participants completed a behavioral task in which they reported the number of perceived different features between 2 sequentially presented stimuli on both the trained and untrained stimulus set, stimuli were presented upright in half of all trials and inverted for the rest. We found an attention effect for both the diagnostic and nondiagnostic features in EEG data. In the feature counting task, participants had better differentiation performance for the trained set than the untrained set, an inversion effect was observed for the trained set.

33.324 **Spatiotemporal dynamics of categorical representations in the human brain and deep convolutional neural networks** Yalda Mohsenzadeh[1,2](yalda@mit.edu), Caitlin Mullin[1], Bolei Zhou[1], Dimitrios Pantazis[2], Aude Oliva[1]; [1]Computer Science and Artificial Intelligence Laboratory, MIT, [2]McGovern Institute for Brain Research, MIT

Not all information in our visual environment is processed equally. Some stimuli are more behaviorally relevant to our growth and survival and thus necessitates faster and more efficient processing. Here we combine the high spatial resolution of fMRI data with the high temporal resolution of MEG data to trace the perceptual dynamics of different categories of relevant visual categories (faces, objects, bodies, animates, scenes). MEG-fMRI fusion revealed that these image categories follow unique paths throughout the ventral visual cortex. For instance, while the neural signal for object and scene categories both reach early visual cortex by 75ms, from there the signal travels laterally and medially, respectively, at distinct speeds. Results from dynamic multidimensional scaling representations reveal that faces separate themselves from the rest of the categories as early as ~50ms. This is especially remarkable as this separation precedes that of animates vs. non-animates, thought to be one of the earliest (most rapid) high-level visual discriminations. Given these category-specific dynamic neural activation maps, we then examined the underlying neural computations that may be driving them. We compared features extracted from layers of state-of-the-art deep networks with our MEG and fMRI data revealing the spatiotemporal correspondence of these networks with the human brain. Results revealed that the early layers of the network corresponded with the analysis of low-level features (peak at 85ms) in early visual cortex, while the later layers corresponded with peak times after 160ms and with brain regions associated with high level semantic processing (i.e. PHC, Fusiform, Lateral Occipital). The integration of neuroimaging techniques with state-of-the-art neural networks can inform on the spatiotemporal dynamics of human visual recognition and the underlying neural computations.

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33.325 **Depth sensitivity of category-selective visual areas to preferred and non-preferred stimuli** Samoni Nag[1](nag.19@osu.edu), Daniel Berman[1], Julie D Golomb[1]; [1]Department of Psychology, The Ohio State University

To make sense of our 3D environment, our brains must transform 2D visual inputs into 3D representations that contain depth information. In human visual cortex, the representation of depth information gradually increases from low- to mid- to higher-level brain regions (Finlayson et al., 2017). Along this hierarchy are category-selective regions (e.g., FFA, LOC, PPA, OPA) that are tuned to a select set of preferred-stimuli (e.g., faces, objects, scenes). An open question is whether these category-selective regions of interest (ROIs) exhibit depth sensitivity in addition to processing their preferred-stimulus categories. In a blocked fMRI experiment, subjects wore red/green anaglyph glasses and viewed a series of category-specific (i.e., faces, objects, scenes) and unspecific (i.e., moving dots) stimuli. Critically, these stimuli were presented at different depths such that they appeared in front of, behind, or at the same depth plane as the fixation point. Comparisons of overall ROI activation between back, middle, and front depths reveal that FFA and LOC may exhibit a front preference whereas scene-selective PPA and OPA exhibit general depth sensitivity (i.e., both back and front > middle). Additionally, motion cortex (MT) exhibits a strong front > middle > back depth preference. This pattern of results might reflect the notion that faces and objects typically appear at near-depths while scenes span both near- and far-depths. A more intriguing question asks whether these ROIs exhibit specific depth preferences for their preferred-stimulus categories. We compared activation in these ROIs across different combinations of depth and stimulus type. Preliminary results suggest that FFA exhibits a stronger front preference for its preferred-stimulus (faces), though it remains unclear whether other ROIs exhibit a specific preference for their preferred-stimuli. These findings shed light on how category-selective areas of cortex incorporate and process depth information.

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33.326 **Awareness of category rule learning** Pooja Patel[1](pooja@knights.ucf.edu), Audrey Hill Zlatkin[1], Andrew Wismer[1], Corey Bohil[1]; [1]University of Central Florida

The theory of category learning called COVIS (COmpetition between Verbal and Implicit Systems) posits that separate brain systems mediate perceptual category rule acquisition. Verbalizable rules are learned explicitly; non-verbalizable rules are learned implicitly. Although the tenets of COVIS have been supported by behavioral and neuroimaging data, few studies have assessed subjective awareness of the strategy learners use in explicit and implicit category rule learning conditions. We conducted a study to examine perceptual classification of visual stimuli (Gabor stimuli varying in spatial frequency and angle of orientation) while also assessing subjective experience of rule learning and use. Participants completed either rule-based (RB; explicit) or information-integration (II; implicit) category learning. After every 40-trial block, participants were asked whether they knew the category rule and to try to describe it in their own words. By the final block, individuals who indicated that they knew the rule over the final 3 blocks of training achieved high accuracy (84% in both conditions). Participants in the RB condition who reported not knowing the rule had accuracy slightly above chance (60%). Many participants in the II condition indicated they did not know the rule, yet nonetheless achieved high accuracy (68%). The results clearly indicate limited ability to articulate the information-integration rule, despite high classification accuracy, as predicted by COVIS for visual stimulus categories.

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33.327 **Sampling from object and scene representations using deep feature spaces** Joshua C Peterson[1](jpeterson@berkeley.edu), Krishan Aghi[1], Jordan W Suchow[1], Alexander Ku[1], Thomas L Griffiths[1]; [1]Department of Psychology, University of California, Berkeley

Decades of research on how people represent visual categories have yielded a variety of formal theories, but validating them with naturalistic visual stimuli such as objects and scenes remains a challenge. The key problems are that human visual category representations cannot be directly observed and designing informative experiments using rich visual stimuli such as photographs requires having a reasonable representation of these images. Deep neural networks have recently been successful in a range of computer vision tasks and provide a way to represent the features of images. Here we outline a method for estimating the structure of human visual categories that draws on ideas from both cognitive science and machine learning, blending human-based algorithms with state-of-the-art deep representation learners. We provide qualitative and quantitative results as a proof of concept for the feasibility of the method. Samples drawn from human distributions rival the quality of current state-of-the-art generative models and outperform alternative methods for estimating the structure of human categories.

33.328 **Towards using human-surrogate models to optimize training sequences during visual category learning** Brett D Roads[1,2](brett.roads@colorado.edu), Michael C Mozer[1,2]; [1]Department of Computer Science, University of Colorado Boulder, [2]Institute of Cognitive Science, University of Colorado Boulder

Previous work on visual category learning has demonstrated that the order of practice trials influences learning outcomes. For example, Carvalho and Goldstone (Memory and Cognition, 2014) provide evidence that a blocking policy results in better learning when the categories are relatively dissimilar, whereas an interleaving policy is superior when the categories are relatively similar. The primary objective of this work is to move beyond heuristic scheduling policies by using human-surrogate models to optimize training sequences. To that end, we must first identify a human-surrogate model that correctly predicts the effect of trial order. To discriminate among various candidate models, we used behavior data collected from a category learning experiment where subjects were randomly assigned to one of three heuristic scheduling policies: blocked, interleaved and nested (a hybrid between blocked and interleaved). The behavioral results of the experiment replicate previous findings demonstrating the importance of trial order. Each model was evaluated using cross-validation, revealing the extent to which the model could generalize to unseen data. Results of the model fitting procedure revealed that commonly used cognitive models are either insensitive to the order of practice trials or not flexible enough to model the empirical pattern of results. In contrast, using a long short-term memory (LSTM) recurrent neural network yields good fits. We further tested the generalization ability of the LSTM model by removing data belonging to one condition and testing it on unseen sequences from all conditions. The LSTM model correctly predicts the order of conditions, except when data from the blocked condition is removed. Taken together, these results suggest that an LSTM model trained on an appropriate span of behavioral data is a promising human-surrogate model.

33.329 **The effect of familiarity and novelty on preference of paintings modulated by complexity and categories** Jiwon Song[1](ssongjw0909@gmail.com), Yuna Kwak[1], Chai-Youn Kim[1]; [1]Department of Psychology, Korea University

Familiarity and novelty are fundamental, competing factors influencing preference (Fantz, 1964; Zajonc,1968). It has been suggested that the effect of familiarity and novelty on preference judgments is modulated by complexity (Berlyne, 1970). Also shown was that the relative influence of familiarity and novelty are distinguishable for preference of different object categories; familiar faces are preferred whereas novel scenes are preferred (Park et al., 2010). Here, we investigated preference of paintings in terms of familiarity/novelty, complexity, and painting categories. 96 painting images were selected for each of the three categories including portrait, landscape, and abstract paintings, which were then divided into high- and low-complexity paintings. Participants were engaged in a sequential preference-judgement task in which a pair of paintings from the same category were presented side by side and participants judged which of the two they preferred and how much (7-point Likert scale between -3 and 3). A painting with median preference was repeatedly presented throughout a block of 15 trials, but always paired with a new painting in a randomized lateral arrangement (Park et al., 2010). The results showed statistically significant main effects of complexity and categories. Participants preferred novel painting to repeated (familiar) one for the paintings with relatively high complexity. Also, participants tended to prefer familiar paintings for the portrait category, whereas they preferred novel paintings for the abstract category. Further analysis revealed participants' preference for familiar paintings with low complexity in portraits whereas novel paintings with high complexity in landscapes. For abstract paintings, novel ones were preferred regardless of complexity, the results of which was more evident in participants with little experience in art. These results suggest that the object category-specific preference is replicated for artistic paintings, which is modulated by complexity in a distinguishable fashion among different categories of paintings.

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Object Recognition: Features, parts, models

Sunday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

33.330 **Preferential use of local visual information in individuals with many autistic traits** Arjen Alink[1](a.alink@uke.de), Ian Charest[2]; [1]Department of Systems Neuroscience, University Medical Centre Hamburg-Eppendorf, Hamburg, Germany, [2]School of Psychology, University Of Birmingham

Individuals with an autism spectrum disorder (ASD) diagnosis are often described as having an 'eye for detail'. This observation, and the finding that individuals with ASD tend to 'see the trees before the forest' when performing the Navon task, has led to the proposal that ASD is characterized by a bias towards processing local image details. However, it is unclear if this bias is restricted to abstract stimuli - like the Navon stimuli - or whether day-to-day vision is dominated by such object details in ASD. If the latter is true, then we expect individuals with a high number of autistic traits to rely more on image details for object recognition. To assess this, we developed a new psychophysical method for determining the relative contribution of low-level image features to recognition. In short, we asked participants to perform a cat vs. dog recognition task based on images containing a randomly selected subset of the original image's features (Gabor wavelets) and used reverse correlation to measure the importance of each feature for recognition. We used this method to demonstrate that object recognition depends more on high-spatial frequency visual features in individuals with an above-median number of autistic traits. Intriguingly, this enhanced reliance on high-spatial

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frequency information was best predicted by autistic traits related to impaired social skills and least predicted by traits related to attention to detail. The findings of this study suggest that the bias towards processing image details ubiquitously affects vision in individuals with a high number of autistic traits, which raises the possibility that such a bias underlies a wide range of real-life abilities and difficulties associated with ASD.

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33.331 **Minimal Recognizable Configurations (MIRCs) elicit category selective responses in high order visual cortex** Galia Avidan[1,2](galiaa@bgu.ac.il), Yael Holzinger[1], Shimon Ullman[3], Marlene Behrmann [4]; [1]Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva, Israel, [2]Department of Cognitive and Brain Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel, [3]Department of Computer Science and Applied Mathematics, Weizmann Institute of Science, Rehovot, Israel, [4]Department of Psychology, Carnegie Mellon University, Pittsburgh, PA, USA

Visual object recognition is performed effortlessly by humans, but in fact, it relies on a series of complex computations which are not yet fully understood. Here we tested a novel model of the representations used for biological visual recognition and their neural correlates using fMRI in human participants. The rationale is based on previous research showing that a set of representations termed Minimal Recognizable Configurations; MIRCs, which are computationally derived and have unique psychophysical characteristics, serve as the building blocks of object recognition. We examined the responses elicited by MIRC images from different categories (faces, objects, and places) throughout the visual cortex and contrasted these responses to that elicited by sub-MIRCs, which are visually similar to MIRCs, but, instead, result in poor recognition and with the response to scrambled, unrecognizable images. Stimuli were presented in blocks, and participants indicated yes/no recognition for each image. We confirmed that MIRCs elicited higher recognition performance compared to sub-MIRCs in all three categories. Whereas fMRI activation in early visual cortex for both MIRCs and sub-MIRCs did not differ from that elicited by scrambled images, high-level visual regions exhibited overall greater activation for MIRCs compared to sub-MIRCs and scrambled images. Moreover, MIRCs and sub-MIRCs from each category elicited enhanced activation in corresponding category selective regions including FFA and OFA (faces), LOC (objects), and PPA and TOS (places). These findings reveal the neural relevance of MIRCs and enable us to make progress on deriving a more complete theory of biological object recognition.

33.332 **The Fusiform Body Area Represents Spatial Relationships Between Pairs of Body Parts** Alexander Bratch[1](abratch92@gmail.com), Stephen A Engel[1], Philip C Burton[2], Daniel J Kersten[1]; [1]Department of Psychology, University of Minnesota, [2]Office of the Associate Dean for Research, College of Liberal Arts, University of Minnesota

Two regions critical for human body perception have been identified in human visual cortex: the extrastriate body area (EBA; Downing et al., 2001) and the fusiform body area (FBA; Peelen and Downing, 2005). While a wealth of evidence suggests that these areas process individual body parts and whole bodies, respectively, the regions' precise roles have yet to be elucidated. Here, we hypothesized that while neurons in the EBA represent individual body parts, neurons in the FBA not only represent whole bodies, but also represent connections between pairs of body parts. We tested this hypothesis by measuring neural responses to body parts that were perceived as either connected or as two disjoint parts. We used 3 Tesla fMRI (2.4 mm isotropic resolution, TE = 30.4 ms, TR = 2 s, multiband factor = 3) to measure BOLD activity in human subjects (N = 8). In an event-related paradigm, a hand and an elbow were presented within circular apertures on a gray background. The parts were presented either in their "normal" connected positions, or rotated within the apertures to induce the percept of disconnected arm parts. Six rotations were used. We observed significantly higher activity in the FBA, but not the EBA, when subjects perceived the parts as connected as opposed to disconnected, averaging across all rotations. When connectedness was perceived in the most physically ambiguous stimulus rotation, activity increased in both lower-level (V2, V3) and higher-level areas (left and right EBA, FBA). Furthermore, a linear support-vector machine discriminated the pattern of activity for parts perceived as connected vs disconnected at a level above chance in the FBA but not the EBA. Together, these findings strongly suggest that the activity in the FBA underlies the perception of spatial relationships between pairs of body parts.

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33.333 **Axes of Real-World Objects: Evidence from Orientation Reflection Errors** Thitaporn Chaisilprungraung[1](tchaisi1@jhu.edu), Michael McCloskey[1]; [1]Johns Hopkins University

Theories of visual object representation often assume that object shapes are represented with respect to a set of internal axes. However, few studies have examined how object axes are defined. Research has suggested that the axes of a simple elongated object (e.g., pen) are defined by the object's elongation (e.g., Sekuler & Swimmer, 2000). But what about the axes of objects that have a side protrusion (e.g., hatchet), or those that possess two equally-elongated parts (e.g., boomerang)? We probed the axes underlying representations of real-world objects in three shape categories: I-shaped, L-shaped, and V-shaped (Fig. 1). We adopted a novel task paradigm that involved analyzing participants' errors in an orientation recall task. Participants viewed an object at a random orientation, and later attempted to reproduce the object's orientation. Previous studies have shown that errors in this task often take the form of reflections across an object axis (e.g., Gregory & McCloskey, 2010). By identifying the reflection axes in participants' reflection errors (Fig.2), we inferred the axes for different shapes of objects. For all three types of stimuli, we consistently observed a pair of perpendicular reflection axes related to salient geometric properties of the objects (Fig.3). For 'I' objects, the axes were defined according to shape elongation, consistent with previous findings. For 'L' objects, the axes were defined by the objects' elongated part (e.g., hatchet's handle), independent of the protrusion (hatchet's blade). For 'V' objects, the axes were defined according to the line that partitions the objects into symmetrical halves. We discuss the implications of these findings for proposals concerning object axis representation. We suggest that our results are not adequately explained in terms of medial axes, or axes defined by the global object outline. Rather, we argue that axes are defined to allow perspicuous representation of the internal arrangement of object parts.

33.334 **Implicit visual recollection: Connecting the dots without top-down knowledge** Rosemary A Cowell[1](rcowell@psych.umass.edu), Patrick S Sadil[1], Kevin W Potter[1], David E Huber[1]; [1]Psychological and Brain Sciences, University of Massachussetts, Amherst

Discovering the Mooney-style Dalmatian dog against its dappled black and white background for the first time enables an observer to rapidly identify the Dalmatian on subsequent occasions. This effect of prior exposure has been explained with a top-down mechanism, in which the identity of the object (a Dalmatian) has been associated with the ambiguous collection of object parts. However, it remains unknown whether associations between the parts of the object – visual associations that are independent of the object's identity – are also learned and later retrieved to aid identification. In this study, we sought evidence for lateral associations between the visual details of objects by examining whether they can be learned and retrieved separately from any top-down influence of object identity. Participants studied objects masked by Continuous Flash Suppression (CFS), which provided exposure to the visual details of the objects while limiting awareness of objects' identities. We contrasted learning under CFS with the study of object names presented as words, which provided object identity without visual details. At test, we measured participants' performance on a part matching task (which could be performed without knowledge of object identity) and a naming task (which required retrieval of object identity based on a part cue). Using a state-trace analysis, we observed a dissociation in task performance that is best explained in terms of separable lateral and top-down associations. In a follow-up study, participants attempted to name the object from a part, then responded as quickly as possible to detect an object emerging from noise: prior study under CFS enabled quicker detection, even after failing to name the object. We conclude that object identification can be facili-

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tated by learning and retrieval of long-lasting associations between the low-level visual parts of an object, and that these learned visual associations can support implicit "visual recollection".

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33.335 **Rod-mediated contour integration measured under scotopic conditions using radial frequency patterns** Oliver J Flynn[1](oliver.flynn@nih.gov), Brett G Jeffrey[1]; [1]OGVFB, National Eye Institute, National Institutes of Health

Photopic shape discrimination tasks using radial frequency (RF) deformation patterns are useful for measuring contour integration and judgments of circularity. Here, we measure shape discrimination using RF patterns under scotopic conditions to investigate rod-mediated contour integration. An RF pattern is a ring with a luminance profile defined by a fourth-derivative Gaussian and a radius deformed by a sine wave. A temporal 2-AFC staircase paradigm was used to measure observers' threshold deformation from circularity using stimuli on a monitor dimmed with neutral density filters to scotopic levels. Radius of the rings (2°-6°), number of radial cycles (5-13), and portion of the stimulus visible (as low as one cycle; 4° and 8° radii; 4, 8, and 16 radial cycles) were manipulated in separate experiments. Two trained observers were tested. Thresholds of approximately 2 minutes of arc were measured consistently across all radii (127 +/- 46 arc sec) and radial cycles (126 +/- 42 arc sec). When large portions of the stimuli were occluded, thresholds improved as visible cycles were added, from one to three cycles, after which thresholds remained constant. This pattern of data was seen regardless of the radius or radial cycles present in the full stimulus. Contour frequency was defined as a measure of the number of cycles per degree of circumference. When only 1 cycle was visible, thresholds decreased as contour frequency increased, from approximately 5 to 3 minutes of arc. In conclusion, under scotopic conditions, contour integration occurs across only a small proportion of the RF pattern stimulus. This is in contrast with photopic data, which finds elevated thresholds even when small portions of the stimulus are occluded. Thresholds are approximately constant across the range of stimulus radii tested, which is consistent with histological measures of rod density as a function of retinal eccentricity.

Acknowledgement: NIH Intramural Program

33.336 **Convergent evidence for global processing of shape** Robert J Green[1](robert.green@research.uwa.edu.au), Edwin Dickinson[1], David R Badcock[1]; [1]The University of Western Australia

There is an ongoing debate over whether there is convincing evidence in support of global contour integration in shape discrimination tasks, particularly when using radial frequency (RF) patterns as stimuli (Baldwin, Schmidtmann, Kingdom, & Hess, 2016). The objection lies in the previous use of high-threshold-theory (HTT), rather than signal detection theory (SDT) to analyse the change in observer thresholds with increasing cycles of modulation. Here we use a discrimination at threshold method to determine whether there is evidence of global processing around the contour of RF patterns. This provided strong experimental evidence for global integration occurring around RF3 and RF5 patterns. To provide a bridge between current and past research we examined the two proposed methods, finding that HTT produced probability summation estimates which were more conservative than SDT (when an appropriate number of channels was used to generate estimates). We found no difference in performance when an RF pattern was presented as the only test stimulus in a block of trials or when two RF patterns were interleaved. For SDT probability summation estimates to account for this it would be necessary for the number of monitored channels to either remain the same for both patterns, or be so high that changing patterns has no observable effect. We reject the idea that probability summation can describe the data. Our results demonstrate the importance of using random phase RF patterns while measuring integration around a contour and provides strong evidence for global shape processing around low frequency RF patterns.

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33.337 **Real-time Optimization for Visual Feature Identification** Jayanth Koushik[1](jayanthkoushik@cmu.edu), Austin Marcus[2], Aarti Singh[3], Michael J Tarr[1, 2, 3]; [1]Center for the Neural Basis of Cognition, Carnegie Mellon University, [2]Department of Psychology, Carnegie Mellon University, [3]Machine Learning Department, Carnegie Mellon University

Vision experiments typically use a small number of stimuli binned into discrete conditions. While effective when testing a small number of hypotheses, restricting the space of experimental stimuli is not optimal when studying visual representation. Particularly, the high dimensionality of feature spaces underlying visual categories implies that it is critical to explore larger stimulus spaces. For example, while some ventral-cortical regions in the human brain are understood to be selective for particular images classes, the underlying visual properties that lead to such selectivity are not well understood. To explicate which properties are important, choosing from a small stimulus set is likely to lead to poor feature identification. However, high-dimensional feature spaces are challenging to search thoroughly. To more efficiently identify the critical features driving brain responses, we adopted an active approach (Leeds et al. 2014, Leeds and Tarr 2016) using a closed-loop system consisting of: 1) collecting EEG signals for a given visual stimulus (an image drawn from a space of distorted face images, or, in a separate experiment, the space of all grayscale images at a given resolution); 2) a Bayesian optimization algorithm (Mockus 1975) that selects the next image to display, whereby it is expected to produce a larger response - in a given EEG time window (e.g. a 50 ms window starting at 170 ms post stimulus presentation) - compared to the previous image. This loop was repeated until we reached a maximum response value (or the system iterated through a fixed number of steps). Validating our method, for the space of distorted face images, results demonstrated replicable convergence towards less-distorted images consistent with the facial selectivity of the N170 ERP signal. For our larger space of unconstrained grayscale images, results revealed characteristics of the mid-level image features critical for visual processing.

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33.338 **Large-scale identification of the visual features used for object recognition with ClickMe.ai** Drew Linsley[1](drew_linsley@brown.edu), Dan Shiebler[1,2], Sven Eberhardt[1,3], Andreas Karagounis[1], Thomas Serre[1]; [1]Cognitive Linguistic & Psychological Sciences Department, Brown University, [2]Twitter Cortex, [3]Amazon

Identifying the visual features driving object recognition remains an experimental challenge. Classification images and related methods exploit the correlation between noise perturbations across thousands of stimulus repetitions and behavioral responses to identify image locations that strongly influence observers' decisions. These methods are powerful but inefficient, making them ill-suited for a large-scale exploration of visual features for object recognition. Here, we describe ClickMe.ai, a web-based experiment for large-scale collection of feature-importance maps for object images. ClickMe.ai pairs human participants with computer partners to recognize images from a large dataset. The experiment consisted of rounds of gameplay, where participants used the mouse to reveal image locations to their computer partners. Participants were awarded points based on how quickly their computer partner recognized the target object as an incentive for them to select features that are most diagnostic for visual recognition. We aggregated data over several months of gameplay – yielding nearly half a million feature-importance maps that are consistent across players. We validated the diagnosticity of the visual features revealed by ClickMe.ai with a rapid categorization experiment, in which the proportion of visible features was systematically masked during object recognition. This demonstrated that features identified by ClickMe.ai were sufficient and more informative for object recognition than those found to be salient. Finally, we found that image regions identified by ClickMe.ai are distinct from those used by a deep convolutional network (DCN), a leading machine vision architecture which is approaching human recognition accuracy. We further describe a method for cueing a DCN to these image regions identified by ClickMe.ai while they are trained to discriminate between natural object categories. DCNs trained in this way learned

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object representations that were significantly more similar to humans' and coincided with more effective predictions of human decisions during visual psychophysics tasks.

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33.339 The underlying mechanism for detecting straight lines. Marie Morita[1](marie.mrt1092@gmail.com), Takao Sato[2]; [1]Graduate School of Letters, Ritsumeikan University, [2]Collage of Comprehensive Psychology, Ritsumeikan University

The detection of straight lines is thought to be realized by balanced outputs from two mechanisms tuned for opposite curvatures (Blakemore & Over, 1976). To examine this supposition, we measured curvature detection thresholds after adapting straight and wavy lines. It was found that curvature detection thresholds were decreased (i.e. sensitivities were increased) after adapting to straight lines. In experiments, we measured curvature detection thresholds, i.e. discrimination thresholds between straight or sinusoidally wavy lines, after adapting to either straight or wavy lines. In the adaptation phase, the vertical adaptation stimuli were presented on both side (1 deg away) of the central fixation point for 5 sec. They were moved along 0.25-deg radius circle at a rate of 0.314 deg/s clockwise or counterclockwise. Then test stimuli, a pair of straight/wavy lines, was presented 1 deg to the right or left of fixation and observers judged which is straight. The threshold was measured by using constant method. The results indicated that detection thresholds after adapting to straight lines were smaller than those after adapting to wavy lines. The adaptation to straight lines should affect equally to the opponent curvature detection mechanisms that subserve curvature detection models based on Blakemore & Over's presumption, and should not affect curvature-detection thresholds. Thus, present results might suggest the existence of detection mechanisms for straight line that is tuned to straight lines instead of curvature.

33.340 Symmetry produces distinctive, not greater BOLD activation in object-selective cortex RT Pramod[1,2](pramodrt@iisc.ac.in), SP Arun[1,2]; [1]Center for Neuroscience, Indian Institute of Science, Bangalore, India, [2]Electrical Communication Engineering, Indian Institute of Science, Bangalore, India

Symmetry is a salient visual property. Previous fMRI studies have shown that symmetry activates object-selective cortex in humans, but this could be simply because symmetric objects evoked distinct patterns of activity. Here we investigated this issue by measuring brain activity using fMRI in human subjects while they viewed symmetric and asymmetric objects in two tasks. In the first task, subjects had to detect object repetitions in blocks of 12 serially presented items that were all symmetric or all asymmetric, but consisted of only silhouettes, only dot-patterns, or mixed silhouettes and dot-patterns. As in previous studies, we found that symmetric dot-patterns evoked greater activity compared to asymmetric dot-patterns in object-selective cortex. However, this advantage was abolished on comparing symmetric with asymmetric mixed objects. Thus, the stronger responses to symmetric objects observed in previous studies are likely due to BOLD signal adaptation. In the second task, subjects had to detect symmetric objects. We found that symmetric objects evoked similar activity in both early visual areas and in object-selective cortex. Yet, linear classifiers trained on multivoxel patterns were able to reliably classify objects as symmetric or asymmetric better in object-selective cortex compared to early visual cortex (average % accuracy = 69% and 64% respectively). Interestingly, distances of objects from the classifier boundary were correlated with symmetry detection time in both regions ($r = -0.65$ and -0.55 respectively, $p < 0.0005$). Taken together, our results show that symmetry perception in humans is mediated by distinctive, not greater activation of object-selective cortex.

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33.341 Infants distinguish light from pigment using temporal, not motion, cues when forming object representations Rebecca J Woods[1](rebecca.woods@ndsu.edu), Savanna Jellison[2], Shea M. Lammers[3]; [1]North Dakota State University, [2]North Dakota State University, [3]North Dakota State University

One of the challenges posed by a world in which visible patterns or textures may be generated from surface reflectance or from externally produced patterns of light is deciphering whether a pattern viewed on an object's surface is a property of the object. If the pattern is a property of the object, then it is advantageous for pattern information to be included in the object representation to facilitate accurate individuation or identification of the object upon later viewings. In contrast, if the pattern is not a property of the object, and is instead a shadow cast on the objects' surface, representing the pattern as an object property can lead to errors in object individuation and identification. In the current study, we tested 7-month-old infants' (N = 40) ability to individuate objects based on pattern information when the pattern was projected and thus, not a true property of the object. In a between-subjects design using the narrow-screen task (Wilcox & Baillargeon, 1998a, b), we assessed object individuation under conditions in which spatiotemporal and motion cues could be used to discern the origins of the pattern. Results indicated that when a pattern was projected onto the surface of an object but was no longer visible when the object was occluded (i.e., appearance of the pattern and object were temporally linked), infants appeared to regard the pattern as a property of the object even though the pattern remained stationary as the object moved. In contrast, when the pattern remained visible during object occlusion, infants regarded the pattern as distinct from the object. Together these finding suggest that when forming object representations based on patterns, 7-month-olds rely more heavily on temporal cues relative to motion cues in order to distinguish patterns inherent to the object from other types of patterns.

33.342 Bayesian shape similarity based on 3D shape skeletons Nathan R J Destler[1](ndestler@psych.rutgers.edu), Manish Singh[1], Jacob Feldman[1]; [1]Rutgers The State University

Shape similarity is a fundamental component of object recognition and shape matching, but computation of shape similarity is poorly understood. In previous work, we proposed a simple similarity measure based on the cross-likelihood of the respective maximum posterior shape skeletons in a Bayesian framework. In the current work we introduce a more principled approach to shape similarity, and also extend it to the 3D case. The new similarity measure is proportional to the posterior probability that two shapes were generated from a common skeletal model, relative to the probability that they were generated from distinct models. One of the key terms entering in this ratio is a probabilistic version of the "edit distance" between one shape skeleton and the other, which expresses how likely one skeleton is to be a transformation of the other. To validate the model, we first applied it to previously-collected human shape discrimination thresholds for (2D) shapes, exploring the degree to which subjects' ability to discriminate simple shapes can be accounted for via skeleton-based similarity. Next, we collected new data in which participants were asked to assign 3D shapes to categories induced from positive and negative examples. In Exp. 1, subjects were asked to classify novel shapes based on a single positive and single negative example. In Exp. 2, subjects were asked to classify shapes based on multiple positive examples (and a single negative example), allowing us to evaluate how subjects' classifications, as well as those of the similarity model, vary as a function of the dissimilarity within the training set. As within-category dissimilarity rises, both the subjects' and the model's responses induce a more "generalized" skeletal model with a topologically simplified structure, entailing a broader category distribution. We interpret these results within the framework provided by the Bayesian approach to shape similarity and shape matching.

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33.343 Tuning of a Deep Neural Network to object and surroundings colors for object recognition. Alban C Flachot[1](flachot.alban@gmail.com), Karl R Gegenfurtner[1]; [1]Abteilung Allgemeine Psychologie, Justus-Liebig-Universitaet-Giessen

Convolutional Neural Networks are the state-of-the-art for object recognition algorithms. However, little is known about the internal representations they build during training, and how internal features relate to object classification. In this work, we examined the color tuning of units in hidden layers of the well known AlexNet and their relevance for the successful recognition of an object. We first selected the patches for which the units are maximally responsive among the 1.2M images of the

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training dataset. Then, we segmented the object being part of the patch from its surroundings, using a k-mean clustering algorithm on the color distribution within the patch. Then we independently varied the color of the object and surroundings to extract the unit's chromatic tuning. We found that in the convolutional layers, 1 through 5, over 36% of the units are sensitive to either the color of the object or its surroundings, reaching over 50% in the fifth layer. Half of these units were sensitive to both object and surround color. In addition, we observed that modifying the color of either object or surround greatly affected the accuracy of the network for recognizing objects. For 74% and 79% of the color tuned units in layer 5, changes of the object color and the surroundings color respectively led to wrong classifications. Our approach allows us to investigate color tuning and object recognition simultaneously and for images the network nodes strongly respond to. Our results show that color plays an important role within AlexNet. Both the color of the object and the surroundings contribute similarly to object recognition.

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33.344 **Nonlinear visual mechanisms for 2D shape discrimination with pose uncertainty** Ingo Fruend[1](ifruend@yorku.ca), John D Wilder[2], James H Elder[1]; [1]Centre for Vision Research, York University, Toronto, ON, Canada, [2]University of Toronto, Toronto, ON, Canada

Humans are very good at recognizing objects from just their 2D outlines. Previous work has modeled discrimination as correlation, using linear systems identification methods to identify internal shape templates (Kurki et al, 2014, JOV; Wilder et al, 2015, Perception). However, Wilder et al. also noted evidence for nonlinearities in human shape discrimination that are not accounted for by the linear correlation model. One function of these nonlinearities may be to extract high-frequency shape information despite pose uncertainty. To test this hypothesis, we reconsider the experiment conducted by Wilder et al. in which human observers discriminated between shapes corrupted with additive Gaussian coordinate noise. A linear model that assumes no internal pose uncertainty can be estimated from these data and 56% of the variance of human responses. If the linear model is forced to account for a large degree of internal pose uncertainty (up to 40% in-plane rotation), explained variance drops to 36% and is only marginally better than chance. However, a deep neural network (DNN) model trained on the human responses completely recovers this lost variance. By analyzing the gradient of the DNN output with respect to the input, we show that the DNN model achieves this by undoing these random internal pose variations to yield a shape representation that is roughly pose invariant. Most importantly, these gradients also show a sensitivity to higher shape frequencies that is not revealed by linear systems identification methods. A DNN model reveals nonlinearities in human shape discrimination. These nonlinearities allow higher shape frequencies to be used for shape discrimination despite substantial amounts of internal pose uncertainty.

33.345 **Convolutional neural networks represent shape dimensions—but not as accurately as humans** Mark D Lescroart[1](mlescroart@unr.edu), David F Fouhey[2], Jitendra Malik[2]; [1]University of Nevada, Reno, [2]University of California, Berkeley

Modern convolutional neural networks (CNNs) trained to categorize images are known to provide good models for many aspects of human vision, including shape perception. However, the relative ability of humans and CNNs on basic 3D shape dimension discrimination is unknown, as is how learning such tasks changes CNN shape representations. To address these issues, we generated a novel, large dataset of rendered generalized cylinders (geons). The dataset consisted of 48 geon classes defined by four shape dimensions. Each geon was rendered in 6075 pose and metric variations. This yielded 291,600 images, enough to fine-tune CNN filter weights. This fine-tuning results in a 68.7% increase in geon classification accuracy compared to CNNs trained on image categorization alone. We used a two-alternative match-to-sample test to compare human performance to CNN performance. On this task, humans achieved higher accuracy (86%) than the best CNN (75%). Both humans and CNNs were more accurate at distinguishing geons that differed in multiple dimensions, and both humans and intermediate layers of CNNs were less accurate when pairs of geons were rotated in different directions. However, humans showed increased ability to distinguish some specific dimensions relative to the CNNs. Finally, analysis of feature activations in intermediate layers of the CNNs revealed that training makes nodes in intermediate layers of the CNNs more selective for specific shape dimensions (e.g. curved axes) while analyses testing generalization across metric variants suggested that CNNs may represent shape dimensions by interpolating between discrete values along each dimension. In conclusion, off-the-shelf CNNs contain some information about 3D shape dimensions, but training CNNs on a shape task can drastically alter this information. Individual nodes in trained networks reflect individual shape dimensions, and trained networks achieve near (but not quite) human-level accuracy at distinguishing complex shapes based on shape information alone.

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33.346 **Predicting object shape and curvature judgments with a new parameterization of shape** Caterina Magri[1](cmagri@fas.harvard.edu), Andrew Marantan[2], L. Mahadevan[3], Talia Konkle[4]; [1]Department of Psychology, Harvard University, [2]Department of Physics, Harvard University, [3]Paulson School of Engineering and Applied Sciences, Department of Physics, Center for Brain Science, Department of Organismic and Evolutionary Biology, Harvard University, [4]Department of Psychology, Harvard University

Some objects look more similar than others on the basis of their shape. The current state-of-the-art models of object shape come from hidden layers of deep convolutional neural nets; however, the parameterization of shape is embedded in millions of parameters. Here, we consider a recently developed alternative model—normalized contour curvature (NCC), as a simpler model to quantify shape structure. This model takes an isolated object image and computes a histogram of curvature-radius values over the level sets of the pixel intensities. We first characterized the overall structure of shape space captured by the NCC model, by computing NCC features (n=51) over a dataset of isolated inanimate objects (N=7000), and employing a principle component analysis. The first four principal components (PCs) explained more variance than a chance reshuffling of the parameters. We next tested the behavioral relevance of these four shape axes. In Experiment 1, behavioral measures of curviness scores were obtained on a test set of 72 images (N=28), using a 5-point curvy-to-boxy scale (Long et al., 2017). In Experiment 2, we obtained measurements of overall shape similarity by having observers (N=16) arrange 72 items in a circular arena so that similar shaped things were nearby. Behavioral ratings of curvature were strongly associated with the 2nd PC score (r=0.64), indicating that perceptual shape dimension is relatively well isolated by this axis of NCC shape space. Additionally, overall shape similarity judgments were modeled within the noise ceiling, placing high weights on the first three principle components (□=0.27, noise ceiling: 0.25-0.33). Taken together, this work demonstrates that the normalized contour curvature model can summarize shape space with a relatively small number of parameters, where the major axes through this shape space are meaningfully related to perceived shape and curvature of inanimate objects.

33.347 **A brain-mediated computational model to estimate perceptual experiences evoked by arbitrary naturalistic visual scenes** Satoshi Nishida[1,2](s-nishida@nict.go.jp), Shinji Nishimoto[1,2,3]; [1]Center for Information and Neural Networks, National Institute of Information and Communications Technology, [2]Graduate School of Frontier Biosciences, Osaka University, [3]Graduate School of Medicine, Osaka University

Recent developments in decoding techniques using functional magnetic resonance imaging (fMRI) allow us to recover perceived visual and semantic contents from human brain activity [e.g., Nishida and Nishimoto, 2017, NeuroImage]. Such decoding techniques have many potential real-world applications (e.g., neuromarketing). However, the measuring cost of fMRI makes it difficult to realize many of such applications. Here, we propose a new decoding framework for estimating naturalistic perceptual experiences with no additional fMRI measurement after model construction. Our framework involves two types of computational models: One is an encoding model that predicts brain activity evoked by arbitrary naturalistic scenes using internal representations of a convolutional neural network. The other is a decoding model

that estimates perceptual experiences from arbitrary brain activity using a semantic vector space. Training these models for each experimental participant requires a set of measured fMRI data while the participant viewed naturalistic movies. However, once the training has been done, the encoding model predicts brain activity evoked by any novel scenes whereas the decoding model estimates perceptual experiences from the predicted brain activity. Accordingly, the combined model does not require any additional fMRI measurements to estimate each participant's perceptual experiences regarding novel scenes. Our results showed that our model well estimated perceptual experiences evoked by novel scenes, which is consistent with the corresponding scene descriptions by human annotators. In addition, the estimation of perceptual experiences varied across participants' models. This variation was significantly correlated with the variation of scene descriptions across annotators, suggesting that the models involve individual variability of perception. Importantly, our framework can use any possible pairs of encoding and decoding models and thus can be potentially applied to many types of decoding with various modalities. Thus, our framework may dramatically improve the applicability of decoding techniques in our society.

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33.348 **Understanding visual recognition via self-supervised deep neural networks** Kandan Ramakrishnan[1](krama@mit.edu), Bolei Zhou[1], David Bau[1], Antonio Torralba[1], Aude Oliva[1]; [1]CSAIL, Massachusetts Institute of Technology, USA

Deep neural networks (DNNs) have been largely successful to model the hierarchy of representations in the ventral visual stream. However, DNNs are trained in a supervised manner with millions of labels to optimize object recognition performance. It is not clear if ventral stream representations are learned in a supervised manner that explicitly optimizes object recognition visual task. In our study, we test the hypothesis that representations learned from different visual tasks in an unsupervised manner corresponds to representations in ventral visual stream. We use DNNs optimized for six tasks without explicit object labels: tracking objects, predicting next frame in a video, predicting object context, solving jigsaw puzzle, moving and object-centric alignment. The layer specific representations of these six DNNs are compared to the representations from the AlexNet DNN. We found that the DNNs trained on predicting spatial object context and solving jigsaw puzzle are most correlated to representations from AlexNet. This suggests that, representations learnt by supervision on millions of labels can be replaced by optimization of properties that are easier to obtain from unlabeled images or videos. To compare DNNs against the ventral visual stream, we use publicly available fMRI data of subjects viewing natural images. Representation similarity analysis shows that the unsupervised DNNs correspond to the hierarchy of representations in the ventral visual stream. This implies that the ventral visual stream encodes not only object categorical representations but properties for a rich set of visual tasks.

Perception and Action: Neural mechanisms

Sunday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

33.349 **Lateralized modulation of self-generated visual stimuli** Batel Buaron[1](batelbuaron@mail.tau.ac.il), Daniel Reznik[2], Roee Gilron[3], Roy Mukamel[1]; [1]Sagol School of Neuroscience and School of Psychological Sciences, Tel-Aviv University, Tel Aviv, Israel, [2]Department of Psychology, Center for Brain Science, Harvard University, Cambridge, MA, [3]Department of neurological surgery, UCSF School of Medicine, UCSF, San Francisco, CA

Sensory stimuli triggered by voluntary action are perceived differently and evoke differential neural activity in sensory regions, relative to identical stimuli triggered by an external source. Such modulations are suggested to occur through corollary discharges sent from the motor system to sensory regions prior to re-afferent stimulus arrival. Given the strong laterality of the motor system, it is plausible that the magnitude of such sensory modulation will also exhibit a laterality effect, depending on the stimulus-triggering hand (right/left). In the auditory domain, we have recently provided evidence in support of such a mechanism. The aim of the current study was to further probe this model in the visual domain. In a behavioral study, 24 subjects judged the relative brightness of self-generated visual stimuli to identical stimuli triggered by the computer. Self-generated stimuli were triggered using either right or left hand and presented either in right or left visual field. Some subjects reported experiencing the self-generated stimuli as brighter and others as darker relative to the externally generated visual stimuli. However, examining the absolute modulation magnitude (proportion of trials) demonstrates that it depended on the relation between stimulus-triggering hand and stimulated visual field. In the left visual field, perception of stimuli triggered with the left hand was more strongly modulated than perception of stimuli triggered with the right hand. In the right visual field, no such effect was found. We further probed this issue using fMRI. Preliminary results from 10 subjects show differential neural response in both visual cortices for identical visual stimuli, depending on the triggering hand. Our findings support the model predicting lateralized modulation of sensory regions, consistent with the known laterality of the motor cortices.

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33.350 **Interaction of visual and semantic features in action-based prediction** Emily Avery[1](eavery@princeton.edu), Nicholas C Hindy[2], Nicholas B Turk-Browne[1]; [1]Yale University , [2]University of Louisville

Actions transform objects in predictable ways, allowing us to generate visual expectations about the consequences of our actions. In a recent study (Hindy et al., 2016, Nature Neurosci), we found that such expectations in visual cortex were signaled by the hippocampus. However, that study examined action-based prediction (i) for novel associations and (ii) among arbitrarily paired stimuli. The hippocampus may have been involved only because of these factors, as they are critical aspects of its role in episodic memory. An alternative account is that the hippocampus is always involved in action-based prediction, regardless of the nature of the underlying memories, given its unique computational abilities, such as for pattern completion. Here we evaluate these accounts in two high-resolution fMRI experiments, considering both novel transformations, as in previous work, and known transformations involving long-term semantic knowledge. One experiment utilized novel transformations between distinct-looking stimuli (e.g., "point" or "wave" transformed a newspaper into a cookie or carrot), whereas known transformations were between visually similar stimuli ("bite" or "break" transformed a whole carrot into one bitten or broken). A second experiment utilized novel transformations between visually similar stimuli (e.g., "smile" or "frown" transformed a t-shirt into one rolled-up or folded), whereas known transformations were between distinct-looking stimuli (e.g., "fry" or "mash" transformed a potato into French fries or mashed potatoes). For both novel and known transformations, responses in early visual cortex were attenuated when an outcome could be predicted from an action, and this predictive attenuation was related to background connectivity with the hippocampus. However, over the long axis of the hippocampus, there were anterior-posterior differences across conditions. Our findings are thus partly consistent with both of the accounts above: hippocampal involvement in action-based prediction seems ubiquitous, but the nature of this involvement can depend on the age and similarity of memories.

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33.351 **Decoding identity and action properties of tools for viewing and pantomiming** Stephanie Rossit[1](S.Rossit@uea.ac.uk), Diana Tonin[1], Fraser W. Smith[1]; [1]School of Psychology, University of East Anglia, Norwich, UK

In our everyday life we often encounter, manipulate and utilize many different tools. Several neuroimaging studies have identified a network of fronto-parietal and occipito-temporal regions that are consistently activated when viewing, imagining and pantomiming tool actions. However, it remains unclear what properties are represented within each region and how these representations overlap or change according to the task used. Here we used multivoxel pattern analysis to investigate the representation of identity and action properties for viewing tools and pantomiming tool-use tasks. Participants (N = 18) viewed pictures of tools (while performing a 1-back repetition detection task) and executed pantomimes of tools actions in response to tool names in different runs. We used familiar tool categories that varied according to two action properties: hand grip (power vs. precision) and hand movement (squeeze vs. rotation). In addition, for each participant separate localizer runs were used to define regions of interest. For both viewing and pantomiming, we found reliable tool-identity decoding in lateral occipital temporal cortex (LOTC), posterior middle temporal gyrus (pMTG), supramarginal gyrus (SMG) and intraparietal sulcus (IPS). Grip type was significantly decoded in LOTC, tool-selective IPS and dorsal premotor (PMd) cortices for both tasks. In addition, movement type was significantly decoded for both tasks in LOTC, pMTG, IPS, SMG, ventral and dorsal PM cortices, and strikingly even in primary motor and somatosensory cortices. These results suggest that areas of both visual streams (LOTC, IPS) encode information about identity and action properties of tools and are in line with claims that viewing tools automatically evokes motor-related representations associated with their use. Finally, cross-task decoding was found in SMG for tool identity and in PMd for grip type suggesting that these regions contain abstract action representations independent of task.

33.352 **Encoding of reaching and grasping intentions from monkey medial parietal cortex** Patrizia Fattori[1](patrizia.fattori@unibo.it), Elisa Santandrea[1, 2], Rossella Breveglieri[1], Annalisa Bosco[1], Claudio Galletti[1]; [1]Dept. of Biomedical and Neuromotor Sciences, University of Bologna, Italy, [2]Dept. of Neurosciences, Biomedicine and Movement Sciences, University of Verona, Italy

Single cell recording in the macaque demonstrated that the medial parietal cortex, besides encoding reaching, is involved also in encoding grasping (Fattori et al., 2010). MVPA applied to fMRI allowed brain imaging studies to confirm the involvement of dorsomedial visual stream in grasping in both monkeys (Nelissen et al., 2017) and humans (Gallivan et al., 2011). The medial parietal area involved in the control of grasping is area V6A, a visuomotor area also known to show motor-related discharges tuned by direction and depth of reaching (Fattori et al., 2005; Hadjidimitrakis et al., 2015), wrist orientation and grip formation (Breveglieri et al., 2016, 2017). Here we compared the activity of single V6A cells during an instructed-delay epoch before reaching and grasping, respectively, applying the same paradigm used in humans (Gallivan et al., 2011) to check whether, when the monkey was preparing the action, neural activity was predictive of the specific upcoming action. In analogy to previous fMRI research, we recorded neural activity when monkeys performed the task in the light, but also added a control condition where monkeys prepared and executed reaching and grasping in darkness. We analyzed the discharges of 91 V6A neurons and found that in about 60% of them, task-selective activity was present before action execution, differentiating between arm/hand movements aimed at reaching a specific location or at grasping an object. Most often stronger pre-movement activity was observed in grasping (68%) vs. reaching task (32%). Most importantly, striking consistency was observed between pre-movement and movement activities, suggesting that the former is a preparatory activity implementing suitable motor programs which support subsequent action execution. These data strengthen the emerging view that areas in the dorsomedial and dorsolateral visual stream act as cooperating routes for controlling the whole act of prehension.

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33.353 **Predicting the Behavioral Similarity Structure of Visual Actions** Leyla Tarhan[1](ltarhan@g.harvard.edu), Talia Konkle[1]; [1]Department of Psychology, Harvard University

Our visual worlds are filled with other people's actions – we watch others run, dance, cook, and crawl. How is this repertoire of visual actions organized? To approach this question, we obtained behavioral similarity measures over 60 videos depicting everyday actions sampled from the American Time Use Survey (ATUS). We then tested how well we could predict this structure using both high-level feature models and neural responses along the visual system. To obtain a similarity space of actions, 20 subjects arranged the videos so that similar actions were nearby (Kriegeskorte & Mur, 2012). Participants' representational structures were moderately similar (noise ceiling: r=0.29-0.36). To understand what properties characterize this representational space, we compared a range of models, reflecting high-level category information (ATUS labels, e.g. "fitness," "grooming"), mid-level models reflecting the role of body parts, and low-level models capturing more primitive visual shape features (gist). Cross-validated prediction scores revealed that category information and body part involvement predicted behavioral similarity moderately well compared to visual shape features (mean leave-1-out τA: body parts=0.15, category=0.14, action target=0.09, gist=-0.01). Additionally, visual cortex responses to the same videos measured using fMRI (N=13) did not predict similarities well (τA =0.08), indicating that this behavioral similarity space is not directly represented within visual cortex. These patterns of data were robust across two different video sets of the same 60 actions. These results on action similarity echo recent work in both object and scene domains (Jozwick, 2017; Groen, 2017): human similarity judgments are best predicted by higher-level properties related to items' functions (what they are), rather than by the mid-level visual features driving neural responses in the visual system (how they look). Broadly, these findings suggest that explicit similarity judgments may derive from an underlying categorical representation rather from a common multi-dimensional feature space.

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33.354 **Mirror neuron system activation differs in experienced golfers compared to controls watching videos of golf compared to novel sports depending on conceptual versus motor familiarity.** Georgina A Amos[1](g.amos@latrobe.edu.au), Philippe A Chouinard[1]; [1]School of Psychology and Public Health, College of Science, Health and Engineering, La Trobe University

Previous research demonstrates that mirror neuron areas respond to visual stimuli in a way that reflects an individual's expertise in a given area (Calvo-Merino et al., 2005, Cerebral Cortex, 15, 1243-1249). For example, expert ballet dancers show greater mirror neuron system activation whilst watching ballet compared to capoeira (a martial arts dance). Both forms of dance share similar movements. These results indicate a greater role for conceptual familiarity over movement familiarity in the mirror neuron system. Our fMRI study aims to further understand the roles of conceptual and movement familiarity by introducing a novel control condition whereby concept and movement can be more precisely disentangled. We examined responsiveness of the mirror neuron system in experienced golfers (N = 12), who watched videos of their sport (golf), a novel sport with similar movements (ice hockey), and a novel sport with different movements (ballet) and compared this activation to that of non-golfers (N = 12). Data were analysed using extracted contrast values from the left ventral premotor area as defined by an independent functional localiser. ANOVA demonstrated a main effect for group in the left ventral premotor area [$F(1, 22) = 5.30$; $p = .03$] with higher BOLD activation for golfers than non-golfers. The interaction was also significant [$F(2, 44) = 5.87$; $p = .005$]. Golfers demonstrated greater BOLD activation from watching golf compared to both ice hockey ($p < .05$) and ballet ($p < .001$), and also from hockey compared to ballet ($p < .01$). No significant differences in activation were detected across video conditions in non-golfers. In conclusion, our results support those of Calvo-Merino et al. (2005) in that mirror neuron areas seem to respond to conceptual familiarity of a dynamic visual stimulus. However, our research also suggests movement familiarity has an important compounding effect with conceptual familiarity in the mirror neuron system.

Acknowledgement: La Trobe University Research Focus Area: Sport, Exercise and Rehabilitation

33.355 **Neural model for the recognition of agency and interaction from motion** Mohammad Hovaidi Adestani[1,2](mohammad.hovaidi-ardestani@uni-tuebingen.de), Nitin Saini[1,2], Martin Giese[1]; [1]Section Computational Sensomotorics, Department of Cognitive Neurology, CIN&HIH, University Clinic Tuebingen, Germany, [2]IMPRS for Cognitive and Systems Neuroscience, Univ. of Tuebingen, Germany

INTRODUCTION: Humans are highly skilled at interpreting intent or social behavior from strongly impoverished stimuli (Heider & Simmel, 1944). It has been hypothesized that such functions might be based on high-level cognitive processes, such as probabilistic reasoning. We demonstrate that several classical observations on animacy and interaction perception can be accounted for by simple and physiologically plausible neural mechanisms, using an appropriately extended hierarchical (deep) model of the visual pathway. METHODS: Building on classical biolog-

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ically-inspired models for object and action perception (Riesenhuber & Poggio, 1999; Giese & Poggio, 2003), we propose a learning-based hierarchical neural network model that analyzes shape and motion features from video sequences. The model has largely a simple feed-forward architecture and comprises two processing streams for form and object motion in a retinal frame of reference. We try to account with this model simultaneously for a number of experimental observations on the perception of animacy and social interaction. RESULTS: Based on input video sequences, the model reproduces results of Tremoulet and Feldman (2000) on the dependence of perceived animacy on changes in speed and direction of moving objects, on its dependence on the alignment of motion and body axis, and the influence of contact with static barriers along the motion path (Hernik et al. 2013). In addition it accounts for results on the detection of chasing behavior (Scholl & McCarthy, 2012) and of fighting (Heider & Simmel, 1944). CONCLUSION: Since the model accounts simultaneously for a variety of effects related to animacy and interaction perception using physiologically plausible mechanisms, without requiring complex computational inference and optimization processes, it might serve as starting point for the search of neurons that are forming the core circuit of the perceptual processing of animacy and interaction.

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33.356 Flexibility of categorical body representation following limb-loss and prosthesis usage in the occipitotemporal cortex

Roni O Maimon-Mor[1,2](ronimaimon@gmail.com), Heidi Johansen-Berg[2], Jody C Culham[3], Tamar R Makin[1,2]; [1]Institute of Cognitive Neuroscience, University College London, [2]FMRIB Centre, Nuffield Department of Clinical Neuroscience, University of Oxford, [3]Brain and Mind Institute, Department of Psychology, University of Western Ontario

The extrastriate body area (EBA) is a body-selective region within the occipitotemporal cortex. EBA has a key role in processing visual information of others' whole bodies and body-parts, however it is unclear to what extent the categorical representation in EBA is influenced by individuals' experience across the lifespan. Here, individuals with acquired or congenital upper limb loss (hereafter one-handers) were tested to investigate how limb loss and body-part substitution (wearing a prosthesis) shape reorganisation in EBA. EBA was independently localised in 32 one-handers and 24 two-handed controls by contrasting images of headless-bodies and objects. Participants viewed images of upper-limbs (lateralised to match the missing side of one-handers), others' prostheses, and one-handers' own prosthesis in an event-related design. Tools, known to activate an area overlapping with EBA, were also presented. Reorganization of EBA was assessed by comparing the distances between these objects using representational similarity analysis. Limb loss did not significantly affect visual representation of the missing upper-limb in EBA, as no differences were found between one-handers' and controls non-dominant limb representation. However, experience-dependent reorganisation was found in one-handers' prosthesis representation. One-handers who use a prosthesis more in daily life, show greater representation of others' prostheses as an independent category, distinct from hands and tools. When observing their own prosthesis, congenital one-handers' visual representation was more similar to upper limbs than tools. This shift of one's own prosthesis representation towards the upper-limb representation was not evident in acquired amputees. This result is consistent with recent evidence suggesting a less rigid categorisation of upper limbs in individuals who lost their hand earlier in life. Together our results suggest that the EBA categorical representation is affected by one's experience with body-part 'substitution'. EBA representation structure might be both adaptable, in creating new categorical representations, and rigid in inflexible category boundaries after development.

33.357 Psychophysiology of Visual-Motor Learning during a Simulated Marksmanship Task in Immersive Virtual Reality

Lawrence Appelbaum[1](greg@duke.edu), Jillian Clements[2], Elayna Kirsch[1], Hrishikesh Rao[3], Nicholas Potter[4], Regis Kopper[5], Marc Sommer[3]; [1]Department of Psychiatry, Duke University School of Medicine, [2]Department of Electrical and Computer Engineering, Duke University, [3]Department of Biomedical Engineering, Pratt School of Engineering, Duke University, [4]Athletic Department, Duke University, [5]Department of Mechanical Engineering and Material Science, Duke University

The ability to coordinate visual information with motor output is essential to a great number of endeavors. In particular, activities such as sports, surgery, and law enforcement rely on efficient reciprocal interactions between visual perception and motor control, allowing individuals to execute precision movements under time-limited, stressful situations. Immersive virtual reality (VR) systems offer flexible control of an interactive environment, along with precise position tracking of realistic movements that can be used in conjunction with neurophysiological monitoring techniques, such as electroencephalography (EEG), to record neural activity as users perform complex tasks. As such, the fusion of immersive VR, kinematic tracking, and EEG offers a powerful testbed for naturalistic neuroscience research. In this study, we combine these elements to investigate the cognitive and neural mechanisms that underlie motor skill learning during a multi-day simulated marksmanship training protocol conducted with 20 participants. On each of 3 days, participants performed 8 blocks of 60 trials in which a simulated clay pigeon was launched from behind a trap house. Participants attempted to shoot the moving target with a firearm game controller, receiving immediate positional feedback and running scores after each shot. Over the course of 3 days of practice, shot accuracy and precision improved significantly while reaction times got significantly faster. The temporal cascade of target launch-locked psychophysiological responses proceeded with significant visual evoked potentials (VEP) (~120-180), followed by eye movements (measured by EOG, ~190ms), then hand (~200ms) and head (~290 ms) movements. Furthermore, greater amplitudes and earlier latencies in the VEP elicited contralateral-to-target trajectories both correlated with better shooting performance, as measured by reaction times and accuracy. These findings, therefore, point towards a naturalistic neuroscience approach that can be used to characterize learning and identify neural markers predictive of marksmanship performance.

33.358 Using EEG to compare brain responses to graspable real-world objects versus 2D images

Francesco Marini[1,2](francesco.pd@gmail.com), Katherine A Breeding[1], Jacqueline C Snow[1]; [1]Psychology Department, University of Nevada Reno, [2]Swartz Center for Computational Neuroscience, University of California San Diego

Visual perception of objects has been investigated traditionally using 2D images. Importantly, however, unlike images, real-world objects provide observers with the potential for manual interaction. In line with this distinction, recent behavioral and fMRI research indicates that real objects may be processed and represented differently to 2D images, although the mechanism for these effects remains unknown. Here, we compared electrophysiological brain responses for real objects with matched pictures to examine whether the underlying temporal dynamics of brain activation differed across the two display formats. We hypothesized that the real objects would be associated with stronger motor preparation signals in dorsal cortex than pictures. Using high-density EEG, occlusion spectacles, and a custom-built experimental apparatus, we recorded brain responses to visual stimuli consisting of 96 real-world graspable objects and 96 2D photographs of the same items printed in high-resolution. We found significant reductions of event-related power for real objects versus pictures over bilateral centro-parietal electrodes in the mu frequency band, consistent with enhanced motor preparation processes. Event-related potentials revealed an early occipital negativity for real-world objects versus images, consistent with stereo depth processing, and late parietal modulations likely reflecting object-recognition processes. Importantly, early occipital differences did not account for centro-parietal motor preparation effects. We conclude that the temporal dynamics of recruitment of sensorimotor regions in the dorsal stream are different for real objects than 2D pictures.

33.360 **Mechanisms of Neuromodulation by Transcranial Current Stimulation** Yinghua Liu[1, 3](yinghua@vision.rutgers.edu), Kohitij Kar[2, 3], Jacob Duijnhouwer[1], Pierre-Olivier Polack[1], Bart Krekelberg[1]; [1]Center for Molecular and Behavioral Neuroscience, Rutgers University - Newark, [2]McGovern Institute for Brain Research, Massachusetts Institute of Technology, [3]Graduate Program of Behavioral and Neural Sciences

In transcranial current stimulation (TCS), low amplitude currents are applied to the head with the goal to modulate neural activity. Cognitive neuroscience studies use this technique to gain insight into the functional roles of brain areas (by modulating excitability) or brain oscillations (by entraining specific rhythms). TCS is also gaining acceptance in applications, for instance to alleviate the symptoms of depression, treat epileptic seizures, or to increase learning and cognition in healthy volunteers. However, little is known about the nature of the intracranial changes induced by transcranial currents. To address this gap in understanding and to improve TCS approaches we are developing awake animal models (mice and nonhuman primates (NHP)) that allow us to study the consequences of TCS using two-photon imaging and multi-electrode recordings in primary visual cortex. At current amplitudes that were well tolerated by the animals, TCS generated intracranial fields that were theoretically sufficient to modulate neural activity (< 1 V/m). Surprisingly, these fields were substantially inhomogeneous even at sub millimeter spatial scales. We speculate that similar inhomogeneities could contribute to the variability of behavioral effects observed in humans. tACS at 10 Hz induced robust and consistent changes in the gain or offset of visual responses of individual V1 neurons in mice, but there was substantial variability across neurons. In mice, anodal tDCS increased excitability while cathodal tDCS had little if any influence. In NHP the consequences of tDCS were also highly variable across neurons. Notably, the same polarity of stimulation could result in opposite effects on excitability. These findings cast doubt on universal statements such as "anodal tDCS increases neuronal excitability while cathodal tDCS decreases excitability". Understanding the origin of the variability and developing a more refined view of the neural consequences of TCS is critical to improve the reliability of the TCS method.

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33.361 **Touchpoints reveal sensitivity to object shape in an individual with visual agnosia and in another who is cortically blind** Robert L Whitwell[1], Melvyn A Goodale[2], James T Enns[1]; [1]Department of Psychology, The University of British Columbia, [2]Department of Psychology, The University of Western Ontario

Object shape is exploited for object recognition and object-directed actions like reaching and grasping. Classic work has shown that information about object shape is expressed in the grasp kinematics and surface-contact points of individuals with compromised shape perception that followed damage to ventral-stream structures (e.g., Goodale et al. 1991). These studies constitute a cornerstone of the two visual systems hypothesis (Goodale & Milner, 1992) and its multi-visual-system descendants. Recent work with normally-sighted populations has shown that the freely chosen end points from point-to-touch movements directed at targets reveal the target-shape's medial axis – a type of shape 'skeleton' (Blum, 1973; Firestone & Scholl, 2014). Moreover, this occurs without participants' having any explicit knowledge of what a medial axis is or what it looks like (Firestone & Scholl, 2014). Here we ask whether or not this medial-axis phenomenon extends to exclusively dorsal-stream representations of shape, by testing DF, who has visual form agnosia resulting from lesions that encompass the shape-sensitive ventrolateral cortical area (LOC) bilaterally, and MC, who is cortically-blind following lesions that also encompass area LOC bilaterally. Each patient touched pebble-like shapes shown on a touchscreen in random positions and orientations. DF and MC could not reliably discriminate amongst the shapes in same/different, oddball, and 1-back tasks, confirming their deficits in visual shape perception. Nevertheless, both DF and MC manually localized the shapes with a high degree of accuracy, showing intact shape localization by the preserved dorsal stream. Moreover, DF's and MC's touchpoints each fell significantly closer to the centre-of-mass and the medial axis of each of the shapes, when compared to sampling distributions for squared-and absolute-mean-deviation metrics derived from random points. These findings indicate that, in addition to the centre-of-mass, other shape metrics such as the medial axis inform dorsal-stream mediated action in the absence of ventral-stream input.

33.362 **Decoding auditory motion direction and location in hMT+/V5 and Planum Temporale of sighted and blind individuals** Ceren Battal[1,2](battal.ceren@gmail.com), Mohamed Rezk[2], Stefania Mattioni[1,2], Roberto Bottini[1], Giorgia Bertonati[1], Valeria Occelli[1], Stefano Targher[1], Olivier Collignon[1,2]; [1]Center for Mind/Brain Sciences (CIMeC)- University of Trento, [2]Institute of Psychology (IPSY) & Institute of Neuroscience (IoNS)- University of Louvain (UcL)

In sighted individuals, a portion of the middle occipito-temporal cortex (hMT+/V5) responds preferentially to visual motion whereas the planum temporale (PT) responds preferentially to auditory motion. In case of early visual deprivation, hMT+/V5 enhances its response tuning toward moving sounds but the impact of early blindness on the PT remains elusive. Moreover, whether hMT+/V5 contains sound direction selectivity and whether the reorganization observed in the blind is motion specific or also involves auditory localization is equivocal. We used fMRI to characterize the brain activity of sighted and early blind individuals listening to left, right, up and down moving and static sounds. To create a vivid and ecological sensation of sound location and motion, we used individual in-ear stereo recordings recorded outside the scanner, that were re-played to the participants in the scanner. Whole-brain univariate analysis revealed preferential responses to auditory motion for both sighted and blind participants in a dorsal fronto-temporo-parietal network including PT, as well as a region overlapping with the most anterior portion of hMT+/V5. Blind participants showed additional preferential response in the more posterior region of hMT+/V5. Multivariate pattern analysis revealed significant decoding of auditory motion direction in independently localized PT and hMT+/V5 in blind and sighted participants. However, classification accuracies in the blind were significantly higher in hMT+/V5 and lower in PT when compared to sighted participants. Interestingly, decoding sound location showed a similar pattern of results even if the accuracies were lower than those obtained from motion directions. Together, these results suggest that early blindness triggers enhanced tuning for auditory motion direction and auditory location in hMT+/V5 regions, which occurs in conjunction with a reduced computational involvement of PT. These results shed important lights on how sensory deprivation triggers a network-level reorganization between occipital and temporal regions typically dedicated to a specific function.

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33.363 **The role of alpha-band frequency activity during performance of a visual-motoric interhemispheric transfer task.** Stephanie L Simon-Dack[1](slsimondack@bsu.edu), Brian Kraus[2], Zachary Walter[1], Chelsea Cadle[1], Shelby Smith[1]; [1]Ball State University, [2]University of Michigan

Interhemispheric transfer (IHT) measured via differences in right- or left-handed motoric responses to lateralized visual stimuli, known as the crossed-uncrossed difference (CUD), is one way of identifying patterns of processing that are vital for understanding the transfer of neural signals. In this paradigm, responses to targets contralateral to hand of response (i.e, crossed conditions) are believed to elicit an interhemispheric transfer, while ipsilateral targets do not (i.e., uncrossed conditions). However, examination of interhemispheric transfer by means of the CUD is not entirely explained by simple measures of response time. Multiple processes contribute to wide variability observed in CUD reaction times, and there is a robust asymmetry where right-handed responses demonstrate faster and sometimes negative CUDs as compared to left-handed responses. Prior research has suggested that intra-hemispheric inhibitory processes may be involved in regulation of speed of transfer. Our study examined electroencephalography (EEG) recordings and time-frequency analysis (TFA) of alpha frequency activity while 18 participants responded to lateralized targets during performance of the classic IHT task, the Poffenberger Paradigm. We found a significant hand x target effect [$F(1, 17) = 6.04$; $p = .025$; $\eta p2 = .26$] for time-locked alpha power, such that targets contralateral to hand of response (i.e., crossed conditions)

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demonstrated larger alpha synchrony, with the biggest difference in alpha activity to targets belonging to right-handed responses. This is notable since the right-hand CUD is often more variable and sometimes demonstrates a paradoxical effect with uncrossed conditions eliciting slower RTs than crossed conditions. Our findings suggest that early motoric inhibitory mechanisms may help explain the wide range of variability typically seen with the CUD.

33.364 **The Emergent Encoding of Human Interactions in the Brain** Jon Walbrin[1](j.walbrin@bangor.ac.uk), Kami Koldewyn[1]; [1]Bangor University, Wales

Recent evidence suggests that static human interactions are encoded holistically, rather than in a part-by-part manner (Baldassano et al., 2017; Ding et al., 2017; Papeo et al., 2017). Another recent study demonstrates that a region of the posterior superior temporal sulcus (pSTS) is selective for social interaction perception (Isik et al., 2017). Interestingly, this region is proximal to regions of cortex shown to play a key role in visual feature integration (Pollmann, et al., 2014). We devised a novel fMRI experiment to determine if the pSTS demonstrates an 'emergent' response to dynamic human-human interactions. Participants viewed brief videos of interactions between two actors engaging in 3 types of interaction (arguing, celebrating, laughing), as well as 'solo' versions of these stimuli (i.e. the same videos, but with one of the actors removed). Using a similar approach to Baldassano et al. (2017), we trained a classification algorithm to differentiate fMRI voxel patterns underlying the perception of each interaction type, then tested performance on untrained interaction patterns and, crucially, on pattern averages evoked by solo videos (i.e. training on interaction patterns, testing on patterns averaged from pairs of corresponding solo stimuli). We hypothesized that multiple regions might significantly classify interactions, but that any region demonstrating emergent encoding of interactive behaviour (e.g. pSTS) would perform significantly worse when cross-classifying to solo pattern averages. We tested this approach in multiple (independently localized) social brain regions. Along with the pSTS, the extrastriate body area and STS face area classified interactions significantly above chance. Crucially, however, the pSTS was the only region to show an emergent encoding effect (i.e. significantly poorer cross-classification of solo pattern averages, compared to interaction classification). These findings provide strong evidence for the role that the pSTS plays in the integration of dynamic human information that is central to interaction perception.

Acknowledgement: European Research Council

33.365 **fMRI response patterns in human somato-motor cortex predict memory advantage for real objects versus their images** Sara Fabbri[1](fabbri.sara@gmail.com), Michael T. Compton[1], Edward B. O'Neil[2], Lars Strother[1], Jacqueline C. Snow[1]; [1]University of Nevada, Reno, [2]University of Toronto

Real objects are more memorable than two-dimensional (2-D) images of the same items, a phenomenon known as the "Real Object Memory Advantage", or ROMA (Snow et al., 2014). Although emerging evidence indicates that real objects are processed differently to images because they afford physical interaction (Gomez, Skiba and Snow, in press), little is known about the underlying mechanism for the ROMA. Here, we used fMRI to identify brain areas that decode, at the time of recollection, the format in which an object was displayed during encoding. Participants first completed a behavioral learning task in which they were asked to remember a large set of everyday household objects. Half of the stimuli were presented as real-world objects; the other half were 2-D images of objects presented on a computer monitor. The images were matched closely to their real-world counterparts for size, apparent distance, viewpoint, background, and illumination, and all stimuli were presented within reach. Participants later completed a recognition task in the MRI scanner. During each scan, participants viewed text descriptors (e.g., 'hammer') and were asked to decide whether each item was viewed as a real object, a 2-D image, or was not viewed at all, during the study phase. Overall, most observers showed superior memory performance for items previously viewed as real objects versus 2-D images, consistent with earlier findings (Snow et al., 2014). Critically, searchlight multivariate pattern analysis (MVPA) of the fMRI data revealed that motor and somatosensory areas in parietal cortex (regions involved during grasping and somatosensation), but not ventral visual areas (regions involved in object perception), were able to decode stimulus format, even though participants did not interact manually with any of the stimuli during the study phase. These results suggest that the ROMA is due to re-activation of dorsal somato-motor networks at the time of retrieval.

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33.366 **EEG decoding reveals functionally independent neural signatures for perceptual maintenance and confidence-based maintenance during conscious perception** Matthew Weaver[1,2](mattdavidweaver@gmail.com), Johannes J Fahrenfort[1,2], Artem V Belopolsky[2], Simon van Gaal[1]; [1]Brain & Cognition Group, University of Amsterdam , [2]Vrije Universiteit Amsterdam

Several influential theories of consciousness attempt to explain how, when and where conscious perception arises in the brain. It is generally accepted that the transition to conscious perception requires feedback from higher level regions. However, the extent of this feedback is still debated. One theory holds that the transition to conscious perception requires feedback from frontoparietal regions (the Global Neuronal Workspace theory; Dehaene & Naccache, 2001), whereas the other maintains that feedback within sensory regions is sufficient to enable conscious perception (the Local Recurrence Theory; Lamme, 2006). Here, we combined a challenging discrimination task with EEG decoding techniques to arbitrate between these competing models of consciousness. Participants discriminated at-threshold masked face vs house stimuli and reported confidence in their discrimination performance. A classifier was trained and tested to discriminate correctly identified face vs house stimuli, separately for high- and low-confidence responses, using both time-specific (on-diagonal) and temporal generalization methods (off-diagonal). The results reveal two distinct decodable patterns of late neural activity. One pattern reflects perceptual confidence, indicating a global cognitive maintenance of the stimulus representation that is consciously reportable (late, on-diagonal decoding). The other pattern (late, off-diagonal decoding) shows maintenance of category information through recurrent processes within visual cortex, and is independent from confidence. This suggests that two functionally independent category-selective representations of a stimulus can temporally co-exist. We confirm the predicted temporal dynamics of how visual stimuli gain access to consciousness and reconcile two competing consciousness theories, by demonstrating for the first time that local recurrence within sensory regions and global maintenance processes in frontoparietal regions temporally co-occur during conscious perception, but that only the latter reflects perceptual confidence.

Perceptual Organization: Grouping and segmentation

Sunday, May 20, 8:30 am - 12:30 pm, Banyan Breezeway

33.367 **Modeling perceptual grouping in peripheral vision for information visualization** Shaiyan O Keshvari[1](shaiyan@mit.edu), Dian Yu[1], Ruth Rosenholtz[1]; [1]Computer Science and Artificial Intelligence Laboratory, Massachusetts Institute of Technology

Perceptual grouping plays a vital role in peripheral vision. The ability to combine separate measurements into coherent wholes supports real world tasks, such as object segmentation. The field of information visualization, however, is just beginning to apply grouping research. In this direction, we study common visualization grouping techniques using an image-computable model of peripheral vision, known as the Texture Tiling Model (TTM). TTM predicts performance on a wide range of tasks, from search in artificial displays to scene categorization. The model encodes a stimulus image as a rich set of image statistics, pooled over regions that tile the visual field and grow in size with eccentricity. We generate predictions by synthesizing images (called "mongrels") which represent the information encoded by the model but are otherwise random. Prior research shows that difficulty doing a task with mongrels predicts difficulty doing the same task peripherally or at a glance. We examine the task of identifying the orientation of a 0.5 deg tall white "T" at 10 deg eccentricity with four randomly oriented white 0.5 deg "T" cardinal flankers 4 deg away, on a mid-gray background. Flankers are grouped together by either of two cues: connectedness or common region. The mongrels show that connecting flankers with white circle arcs does not prevent them from interfering with the target. Interestingly,

Sunday AM

placing the flankers in front of an annulus of different gray-level, called the common region, decreases interference, but only when this common region is between the mid-gray background and white in gray-level. Likewise, highlighting only the target with a small square region helps, but only if the region is darker than the background. This suggests that grouping by common region aids visualization, but only when it accentuates the target or camouflages distractors. Further experiments will test these model predictions on existing visualizations.

33.368 **Perceptual Grouping of Dichoptic Plaids** Emily Slezak[1,2](easlezak@uchicago.edu), Andrew J Coia[1], Steven K Shevell[1,2,3]; [1]Institute for Mind & Biology, University of Chicago, [2]Department of Psychology, University of Chicago, [3]Department of Ophthalmology & Visual Science, University of Chicago

Multiple ambiguous objects in view simultaneously are perceived as identical more often than chance. Standard binocular rivalry experiments reveal grouping by color, pattern, and other Gestalt principles. These so-called "coherent" identical percepts can be formed by grouping spatially-separated objects across the two rivaling images, resulting in complete suppression of one coherent percept in favor of the other. Perception of one or the other coherent image, however, does not always occur; instead, rivalrous, orthogonal gratings are sometimes seen as a plaid - a percept that never occurs in either eye's stimulus. Can coherent, grouped plaid percepts occur, given that plaid is an integrated percept from both eyes' stimuli? METHODS All conditions presented pairs of dichoptic, equiluminant gratings, one pair above and one below fixation. These gratings were exchanged between the eyes at 3.75Hz in interocular-switch rivalry. Alternating gratings always had orthogonal orientations to allow for a plaid percept if fused, and could differ in chromaticity ('red' rivaling with 'green') or not (orthogonal gratings both 'red' or both 'green'). Additionally, the pair of gratings presented above fixation could be either the same non-rivalrous chromaticity as below, different non-rivalrous chromaticities, both with rivaling chromaticities, or one pair with rivalrous chromaticities and one with non-rivalrous chromaticities. Observers reported grouped percepts when both gratings appeared to be the same orientation (left-tilted or right-tilted) or both plaid. RESULTS/CONCLUSIONS When single orientation gratings were perceived above and below fixation, they appeared the same (both left-tilted or both right-tilted) more often than chance for all conditions. When plaids were perceived, most observers perceived grouped single-chromaticity plaids, even if the non-rivalrous chromaticity above fixation did not match the chromaticity below fixation. This indicates that grouping can occur at the level of integrated percepts (plaids) and is not limited by an individual feature difference such as color.

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33.369 **The perceptual capacity of concurrent grouping of colored dots by similarity and by dissimilarity** Peng Sun[1](peng.sun@uci.edu), Chales Chubb[1], Charles Wright[1], George Sperling[1]; [1]University of California Irvine

When presented with a single brief exposure of 12 dots colored with the same but unknown identical color interspersed among 14 dots of 7 different colors, subjects can accurately report the centroid of either the subset of homogeneous dots or the subset of heterogeneous dots, or the centroid of all the dots. When asked to locate the centroids of both heterogeneous and homogeneous subsets simultaneously (two responses), performances are little affected compared to single response controls. We interpret these remarkable data in terms of subjects' ability to simultaneously create two groups of stimulus items according to higher-order attributes (e.g. homogeneity or heterogeneity), and to compute summary statistics, e.g., centroids, on the items within a group. Whereas perceptual grouping by similarity is a cornerstone of Gestalt theory, the ability of subjects to also concurrently group by dissimilarity makes similarity tautological. Prior experimental demonstrations of grouping have been largely qualitative, the present experiments reveal the relative weight every color of dot among targets and distracters to the judged centroid in both the homogeneous and heterogeneous sets, and thereby demonstrate a high degree of selectivity in the contribution of dots to a particular centroid. The paradigm also provides a lower-bound estimate of the number of dots that contribute to a centroid judgment--over eight from each subset--an extraordinary number. In a partial report procedure, when reporting whether a cued dot was present or absent in the stimulus display, subjects have conscious access to less than 4 stimulus dots, enormously fewer than the >16 available to the pre-conscious centroid computation. The direct quantitative measurements enabled by the centroid paradigm reveal a great selectivity and an extraordinary information capacity of the pre-conscious perceptual grouping process.

33.370 **Contrast dependency of Gestalt proximity principle** Lee Lin[1](b03207028@ntu.edu.tw), Chien-Chung Chen[1,2]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Center for Neurobiology and Cognitive Science, National Taiwan University, Taipei, Taiwan

The studies of the Gestalt principles in the literature focused on the spatial arrange of stimulus component and often neglects the effect of luminance contrast. However, luminance contrast may play a major role in perceptual grouping (Wilson & Wilkinson, 1998; Lin et al., 2017). The current study investigated contrast dependency of Gestalt proximity law with a tripole Glass patterns (tGPs) paradigm. A tGPs consists of randomly-distributed sets of three dots, or tripole. Each tripole contained one anchor dot and two context dots. An observer would perceive a clockwise (CW) or counter-clockwise (CCW) spiral global percept by grouping the anchor dot with either one of the context dot. We changed luminance contrast of the context dots ranging between -30 and 0 dB, while the luminance contrast for the anchor dot was fixed at -15 dB. The anchor-context distance varied between 2.5 and 20 min. Participants were asked to report whether they perceived CW or CCW in the tGP in each trial. When the luminance contrast of both context dots was low, the probability of perceiving a CW spiral increased when the distance between CW context dot and the anchor dot decreased, as would be predicted by the proximity grouping principle. However, when the luminance contrast was high, the probability of perceiving a CW spiral decreased as the distance between CW context and anchor dot decreased. This result was in opposite from the prediction from the proximity law. These results suggested that the Gestalt proximity law is subject to contrast control. Our result can be well fit by a divisive inhibition model in which the response for a global pattern is the summed excitation of linear filters, each for a local dipoles, raised by a power and then divided by a divisive inhibition signals from all other dipoles.

33.371 **Is configural superiority associated with a cost in processing spatial information?** Pieter Moors[1](pieter.moors@kuleuven.be), Thiago Leiros Costa[1], Johan Wagemans[1]; [1]Department of Brain and Cognition, KU Leuven, Leuven, Belgium

A recent study suggested that stimuli leading to configural superiority effects (CSE) have higher information processing costs than their constituent parts presented alone (Bratch et al., 2016). Embedding the stimuli in noise revealed lower contrast thresholds for part-stimuli compared to configural stimuli. We reasoned that the use of external noise disrupted the processing of emergent features at low contrasts, and that the benefit for part-stimuli would not hold across the whole contrast range. We reanalyzed Bratch et al.'s data and observed that the slopes of the psychometric functions showed a part-based benefit at lower contrasts and a configural benefit at higher contrasts. Such a slope difference was absent for their control experiment, in which the configural stimulus was not intended to elicit any CSE. To corroborate the results of this reanalysis, we conducted a replication and extension experiment of Bratch et al. We measured contrast thresholds in an odd quadrant task for three types of displays: "good" Gestalts (inducing CSE), "bad" Gestalts (not inducing CSE) and their constituent parts. This design allowed us to also directly compare good and bad Gestalts. In a second experiment, we assessed the processing of Gestalts at threshold when external noise is absent. The results revealed: (1) a successful replication of Bratch et al.'s results; (2) lower thresholds for good Gestalts compared to bad Gestalts in both experiments; (3) lower thresholds for good Gestalts compared to their parts in the no-noise experiment; (4) steeper slopes of the psychometric functions for good Gestalt stimuli, suggesting nonlinearity of emergent features; (5) threshold differences for good Gestalts and their parts were strongly dependent on quantifications of contrast: RMS contrast revealed

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benefits for parts whereas Weber contrast revealed benefits for Gestalts. In sum, these results challenge the generality of the claim that configural processing involves less efficient information extraction.

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33.372 **Testing Levelt's laws for interocular grouping using contrast- and luminance-modulated stimuli** Jan Skerswetat[1](Jan.skerswetat@anglia.ac.uk), Monika A. Formankiewicz[1], Sarah J. Waugh[1]; [1]Department of Vision and Hearing Sciences, Faculty of Science and Technology, Anglia Ruskin University

Perceptual rivalry or grouping can arise when different stimuli are presented to the two eyes. We initiated interocular grouping (IOG) using orthogonally oriented split-gratings for which complementary halves were of the same stimulus type. Stimulus types were luminance-modulated (LM) or contrast-modulated (CM) noise gratings. Levelt's modified laws (Brascamp et al. 2015) were tested for IOG using these stimuli. Estimates of multiples above contrast detection threshold served as a measure for the visibility of each stimulus component. A stimulus presented to one eye (with the two orientations) could have been all LM (LMvsLM) or included LM and CM types (LMvsCM). The gratings had a spatial frequency of 2/deg and a diameter of 2deg. The noise was interocularly correlated and had an amplitude of 0.2. To test the first three laws, the CM component was always 7x visibility and the LM visibility was one of 3.5, 7, or 44x. To test the fourth law, the visibility of the whole stimulus in both eyes was either 3.5 or 7x (LMvsCM and LMvsLM) and 44x (LMvsLM). Nine participants with normal binocular vision indicated whether a horizontal, vertical, piecemeal, or superimposed percept was seen. The results for the LMvsLM condition tended to follow the predictions based on Levelt's modified laws, whereas the results for the LMvsCM condition tended not to. These results are similar to findings from a previous investigation using conventional binocular rivalry with full CM and LM gratings (Skerswetat et al. 2016, VSS poster). Our findings suggest that conventional binocular rivalry and IOG with LM stimuli are processed differently compared to when both stimulus types are used.

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33.373 **The role of perceptual and contextual information in social event segmentation** Nida Latif[1](nida.latif@mail.mcgill.ca), Francesca Capozzi[2], Jelena Ristic[3]; [1]Department of Psychology, McGill University, [2]Department of Psychology, McGill University, [3]Department of Psychology, McGill University

Social event segmentation, or parsing the ongoing dynamic content into discrete social events, is thought to represent an underlying mechanism that supports the expert human ability to navigate complex social environments quickly and seamlessly. Here we examined whether social event segmentation is influenced by the appropriate social context. To do so, we created two video clips, one in which several events unfolded in a contextually consistent manner (Contextual condition), and the other, in which the order of these events was scrambled using a random sequence (Non-contextual condition). Participants viewed each clip and were asked to mark social and non-social events. Results demonstrated that the same information was identified as constituting event breakpoints within each contextual and non-contextual clip. However, increased group response agreement for social relative to non-social event boundaries was observed in the Contextual relative to the Non-contextual condition. Thus, while perceptual information appears to underlie the identification of social and non-social events, contextual information acts to reduce the uncertainty regarding event boundaries, specifically while parsing social information.

33.374 **Bound Together: Social binding leads to faster processing, spatial distortion and enhanced memory of interacting partners.** Tim Vestner[1](tv551@york.ac.uk), Steven P Tipper[1], Tom Hartley[1], Harriet Over[1], Shirley-Ann Rueschemeyer[1]; [1]University of York, Department of Psychology

Feature-binding of objects into perceptual wholes is a well-known phenomenon but until now mostly researched in the context of early vision and low level features, such as colour or proximity. A similar binding process utilising higher level information in order to bind people into interacting groups could facilitate faster processing and enhanced memory retention of social situations. We investigate this possibility in three experiments and show that social interaction is a valid binding mechanism that leads to faster processing in visual search using an odd-quadrant paradigm (Experiment 1). In spatial judgment tasks the same grouping process leads to spatial distortions with interacting individuals being remembered as physically closer (Experiment 2). Finally, we show that memory retention of group-relevant and irrelevant features is enhanced when recalling interacting partners in a surprise memory task (Experiment 3). Alternative explanations on the basis of known principles of grouping as well as low level perceptual features or attention orienting cues were ruled out. We conclude that late-stage grouping processes bind individuals into groups on the basis of their perceived interaction. Identifying the automatic encoding of social interactions in visual search, distortions of spatial memory and object property memory, opens new approaches to studying social cognition and possible practical applications.

33.375 **Spatial Representations of the Visual World are not Coordinate Reference Systems** Pedro Sztybel[1](psztybel@nd.edu), Bradley S Gibson[1], Michael J Wenger[2]; [1]University of Notre Dame, [2]The University of Oklahoma

Coordinate reference systems have been essential conceptual tools for understanding how space is represented in the brain. For instance, the representation of space on the retina is commonly construed as a polar coordinate system with the origin centered on the fovea and with eccentricity (distance) and polar angle (direction) representing two orthogonal, separable dimensions of space. However, although the concept of a coordinate reference system has been essential to understanding how encoded space is defined, the concept leads to an important theoretical prediction that has generally gone untested: specifically, that location is represented in terms of at least two perceptually separable and potentially independent dimensions. The present study addressed the extent to which luminance onsets are encoded as separable vs. integral spatial dimensions using general recognition theory (Ashby & Townsend, 1986). A total of 15 observers performed a complete identification task, in which distance and direction were factorially manipulated at three levels of each dimension (see Figure 1 in the supplemental materials for a description of the stimulus displays), and which required a nine-alternative response task that allowed for direct simultaneous assessment of each observer's perception of both stimulus dimensions on each trial. A sufficient number of trials were run to allow for distributional analyses of response frequencies and latencies at the individual subject level. Response frequencies and latencies were analyzed with respect to marginal response invariance and report independence (Townsend, Houpt, & Silbert, 2012), and the results were used to fit multivariate Gaussian discrimination models. The results indicated that direction and distance were not encoded as separable sources of information, either perceptually or decisionally, with there being evidence for a lack of independence across dimensions. These findings suggest that coordinate reference systems are not appropriate conceptual tools for understanding the composition of spatial representations of the visual world.

Attention: Capture

Sunday, May 20, 8:30 am - 12:30 pm, Pavilion

33.401 **Revisiting Attention Capture by Motion Onset** Kendra C Smith[1](kendrasmith@wustl.edu), Richard A Abrams[1]; [1]Washington University in St. Louis

Several properties of visual stimuli have been shown to capture attention, one of which is the onset of motion (Abrams & Christ, 2003). However, whether motion onset truly captures attention has been debated (e.g., Sunny & von Mühlenen, 2011): It has been argued that motion onset only captured attention in previous studies because properties of the animated motion used in those experiments caused it to be "jerky" (i.e., there were large gaps between successive locations of moving stimuli as they were drawn on the computer monitor). The present study sought to further examine these claims by employing natural motion rather than animated motion. In two experiments, electric motors controlled the motion of salient objects that were placed near alphanumeric stimuli. In Experiment 1, two movable objects were each positioned near two figure-eight placeholders. The objects were either moving or stationary at the beginning of each trial but underwent a motion change after a 3.2s preview. At that

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time the figure-eight placeholders changed to letters, and participants searched for the target. The target could appear near an object that (a) never moved, (b) was continuously in motion, (c) stopped moving, or (d) started moving. Experiment 2 employed a similar method but a device with four motor-driven objects that produced natural motion was used to compare all four motion types simultaneously. The results of both experiments indicate that motion onset captures attention. Therefore, it is not only “jerkiness” of animated motion that captures attention, as found in previous studies, but instead the onset of natural motion can capture attention.

33.402 **Investigating the role of the Frontal Eye Field (FEF) and of the Intraparietal Sulcus (IPS) in attentional capture: A TMS study** Carlotta Lega[1](carlotta.lega@univr.it), Oscar Ferrante[1], Elisa Santandrea[1], Luigi Cattaneo[1,2], Leonardo Chelazzi[1,2]; [1]Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Italy, [2]Istituto Nazionale di Neuroscienze (INN)

In visual search, the presence of a highly salient, singleton distractor interferes with selective processing of the target. This is partly due to the unwanted attentional shift to the salient stimulus, the so-called attentional capture effect, resulting in a measurable cost in performance. The stimulus–driven mechanisms mediating capture are antagonized by goal-driven mechanisms, which on the one hand maintain focus on the sought target while on the other attempt to suppress distractor processing. Lately, there has been growing interest toward the neural mechanisms supporting singleton capture, as well as those responsible for distractor suppression. Although neuroimaging data converge to indicate a key role of parietal and frontal-prefrontal regions in dealing with visual distractors, their respective role and any hemispheric specialization are still to be fully understood. Here we used transcranial magnetic stimulation (TMS) to shed light on the possible causal role of two key regions of the dorsal attention network in mediating and opposing attentional capture by a salient distractor. Participants were required to discriminate the direction of a target arrow while ignoring a task-irrelevant salient distractor, when present. Immediately after display presentation, TMS was delivered either to the Intraparietal Sulcus (IPS) or the Frontal Eye Field (FEF) on either side of the brain. Compared to a suitable sham condition, stimulation of the right FEF - but not of the left FEF – reliably reduced the cost engendered by the salient distractor, irrespective of the visual hemifield of target and distractor presentation. We found comparable but much weaker effects following right IPS stimulation. These findings provide direct, causal evidence that the right frontal cortex houses key mechanisms to limit interference from an irrelevant but attention-grabbing distractor, and further confirm previous evidence of right-hemisphere dominance at least in some forms of attention control.

Acknowledgement: University of Verona, Italy Italian Government

33.403 **10Hz Transcranial Alternating Current Stimulation (tACS) Transiently Reduces Visual Distraction** Yao Li[1](li.yao@pku.edu.cn), Fang Fang[1,2,3,4]; [1]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China , [2]School of Psychological and Cognitive Sciences, Peking University, Beijing, China, [3]IDG/McGovern Institute for Brain Research, Peking University, Beijing, China, [4]Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China

Transcranial alternating current stimulation (tACS) is a noninvasive method to modulate brain oscillation and cognitive functions. Considering the important roles of alpha- and gamma-band neural oscillations in spatial attention, we aimed to investigate whether and how the application of tACS in the alpha and gamma bands could modify the distraction of a task-irrelevant but salient stimulus during visual search. In the current study, fourteen participants received three kinds of 2 mA alternating current stimulation (Sham, 10Hz or 40Hz) at either the left or right inferior parietal area (P5 or P6) on six different days, with an at least two-day interval between stimulation conditions. The stimulation order was randomized across participants. Each stimulation condition consisted of 3 consecutive sessions and each session took approximately 12 min. Participants performed an additional singleton task (Theeuwes, Perception & Psychophysics, 1992). Note that participants only received tACS during the first session. There was no tACS in sessions 2 and 3. Distractor effect (DE = RT_distractor – RT_non-distractor) was calculated as an index of attention captured by a colored singleton, and then submitted to a repeated-measures ANOVA with within-participants factors of time (sessions 1 to 3), hemisphere (left vs. right) and treatment (10Hz vs. 40Hz vs. sham). We found a significant interaction between time and treatment. Compared to the sham condition, DE in the 10Hz condition was significantly lower in session 1. Interestingly, this effect disappeared in sessions 2 and 3. The 40Hz tACS made no difference in all the 3 sessions. These findings demonstrated that the 10Hz tACS could decrease visual distraction from a colored singleton. However, this effect was short-lived and it no longer manifested when the tACS was terminated. These findings also help to explore the possibility of modulating visual search performance by tACS.

33.404 **Tracking frontal involvement in the control of attention with EEG: frontal signal related to both termination and prevention of attention misallocations** Heinrich R. Liesefeld[1,2](Heinrich.Liesefeld@psy.lmu.de), Anna M. Liesefeld[1], Hermann J. Müller[1,3]; [1]Department Psychologie, Ludwig-Maximilians-Universität München, Germany, [2]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, Germany, [3]Department of Psychological Sciences, Birkbeck College, University of London, UK

Can people exert control over their attention allocations or is attention mainly driven by external factors? A positivity measured at posterior EEG sites contralateral to salient distractor singletons (distractor positivity, PD) has been linked to the active suppression of task-irrelevant stimuli during visual search. Given the extensive literature on cognitive control that ascribes the critical role of top-down control to (pre-)frontal brain areas, the PD likely reflects merely the consequence of attentional control (e.g., suppression at the level of the search-guiding priority map), rather than a cognitive control process proper. fMRI studies observing increases in frontal cortical activity when a distractor is present lack the temporal resolution to tell whether the frontal activity precedes the posterior activity, as would be expected if frontal areas exert control of priority signaling, or whether frontal activity is a mere by-product potentially reflecting retrospective evaluation of distractor handling. EEG, in contrast, provides the temporal resolution necessary to solve such questions. We were indeed able to extract a frontal EEG signal emerging around 200 ms after search-display onset whenever a salient distractor was present in two types of trial events: when a salient distractor did capture attention (i.e. when a misallocation had to be terminated) and when it was successfully suppressed before it could do so (i.e. when a misallocation was prevented). In both situations, the frontal component preceded the parietal PD component, lending support to the hypothesis that executive control processes residing in frontal brain areas cause the suppression of irrelevant distractor locations at the priority map, as reflected by the posterior PD. In any case, the early involvement of frontal areas indicates a critical role for executive control processes in distractor handling at an early stage of visual processing.

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33.405 **A potential benefit of eye blinks? Performance in RSVP tasks after blinks (and blanks)** Jit Wei (Aaron) Ang[1](angj0055@e.ntu.edu.sg), Gerrit Maus[1]; [1]Nanyang Technological University

We blink more often than is required for eye lubrication, frequencies fluctuating greatly depending on task. Is there a benefit of increased blink rates? Some evidence suggests that blinks cause deactivation in dorsal attention areas (Nakano et al., 2013), possibly causing a “reset of attention”. Contrariwise, retinal transients such as abrupt stimulus appearance, usually causing enhanced discrimination performance (e.g., Yantis & Jonidas, 1984), are known to be suppressed in cortical processing after eye blinks, particularly in parietal areas (Golan et al., 2016; Hari et al., 1994). We tested the effect of blinks and stimulus blanks on performance in a rapid serial visual presentation (RSVP) task. In experiment 1, participants identified a target digit embedded in a random stream of letter distractors, presented at 60 ms each. Participants were asked to blink once any time during the presentation. An eye tracker was used to identify blinks in real-time and present the target at varying delays after blink offset. In

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a separate condition, stimulus blanks using shutter glasses emulated the temporal properties of each observer's voluntary eye blinks. We found transient enhancements of performance (~15% increased accuracy) for targets appearing up to 180 ms after blink offset for both conditions. In experiment 2, participants judged numerosity of targets—a task supposedly dependent on parietal areas. Performance was poorer after natural blinks compared to artificial blanking up to 180 ms after blink offset. In both experiments we also observed a boost 800-1000 ms after blink offsets. Experiment 3 used natural scene distractors and animals as targets. Natural blinks again showed boosted performance up to 180 ms after blink offset. Based on the data collapsed across the 3 experiments, we suggest that the early boosts are due to transient effects, whereas the later boosts at 800-1000 ms are due to an attentional reset mechanism.

33.406 **The role of probabilistic expectations on the suppression of salient distractor** Bo-Yeong Won[1](bywon@ucdavis.edu), Joy J Geng[1,2]; [1]Center for Mind and Brain, University of California, Davis, [2]Department of Psychology, University of California, Davis

Recent work has shown that the efficiency of attentional selection can be facilitated by not only the enhancement of target features but also the active distractor suppression (Geng, 2014). In this study, we explored the role of probabilistic expectations in the suppression of salient distractors. In three experiments, participants were asked to report a bar's orientation inside a gray shape singleton (i.e., target) among gray distractors. Critically, on some trials, one distractor was a color singleton, which captures attention (i.e., singleton capture; Theeuwes, 1994). In Experiment 1, we manipulated the color singleton's variability (fixed or various), and the likelihood of the occurrence (80% or 20%). The results showed the color variability (3 colors in Experiment 1 and 192 colors in Experiment 3) does not affect singleton capture. In contrast, the likelihood of occurrence strongly modulates singleton capture (RT and first fixation). When the singleton has a low-likelihood of occurrence, attention is strongly captured compared to when a high-likelihood of occurrence. In Experiment 2, we tested whether the difference is due to better proactive or reactive suppression by randomly inserting a probe display on some trials that contained a letter inside each shape. Participants were asked to report the letters they saw (Gaspelin et al., 2015). The probe could occur either just before the search display (pre-probe trials) or after (post-probe trials). We found a high probability of report for the letter on the singleton distractor in post-probe trials in the low-likelihood condition suggesting attention is captured by the color singleton, but a low report in the high-likelihood condition, which suggests the capture is proactively suppressed when the color singleton occurs frequently. Our findings demonstrate attentional capture is more sensitive to the frequency than specific features, and that frequency determines whether proactive suppression mechanisms can be exploited to facilitate performance.

33.407 **Capturing the response dynamics of attention capture with mouse tracking** Michael Dieciuc[1](MichaelD180@gmail.com), Walter R Boot[1]; [1]Psychology, Florida State University

Most studies that have investigated attention capture have done so looking at response-times, eye movements, and EEG measures. In contrast, the current study used mouse-tracking, a continuous online measure of response dynamics, to investigate attention capture and the mouse tracking metrics most sensitive to capture. Participants completed a variant of the oculomotor capture paradigm, where instead of making an eye movement to the target, participants used their mouse to click on it as quickly as possible. Participants were shown a screen with 4 green boxes after which 3 of them turned white. Participants clicked on the remaining green box (their target). On half the trials, a new white box appeared on the screen (onset) that was either on the same side as the target or on the opposite side. Overall, our results demonstrated that abrupt onsets influenced trajectories. Crucially, while there were differences in area under the curve ($F(2, 48) = 12.3$, $p < .001$, $n2p = .34$), there were no differences in RT ($F(2, 48) = 1.69$, $p = .2$, $n2p = .07$) or initiation time ($F(2, 48) = .135$, $p = .87$, $n2p < .001$). Relative to trials where there were no onsets, onsets on the same side as the target facilitated trajectories (more direct paths, $t(24) = 2.1$, $p = .049$) whereas onsets on the opposite side of the target interfered with trajectories (less direct paths, $t(24) = 4.2$, $p < .001$). Given mouse-tracking's continuous and high-density measure of behavior, these results suggest that response dynamics might be a more sensitive measure of attention capture than relatively discrete and ballistic measures like response time or saccades. Continuously measuring response dynamics as they unfold over time and space may ultimately be helpful in disentangling the long-standing debate regarding the nature of attention capture.

33.408 **No suppression of stimulus-driven capture with distractor and target singletons of the same (color) dimension** Hanna Weichselbaum[1](hanna.weichselbaum@univie.ac.at), Ulrich Ansorge[1]; [1]University of Vienna, Austria

In visual search, presenting target and distractors at the same time, an irrelevant distractor not matching to the current search goals can capture attention in a stimulus-driven way. Recently, Kerzel and Barras (2016, JEP:HPP, 42) found that (capture by) such a distractor was successfully suppressed, unless the distractor unpredictably changed its color over the course of the experiment. This was found with a color-distractor when participants searched for a shape-target. In our study, we tested if a known color-distractor can also be suppressed when participants searched for a target defined in the same dimension as the distractor (i.e., color). In no-distractor trials, participants searched for a color target among seven gray non-targets. In the first and last blocks, in half of the trials, a non-matching singleton of a fixed and, thus, known color replaced one of the non-singletons. In contrast, in the second (control) block, distractors could change colors. This block was also used to demonstrate that results were not due to singleton search, as a contingent-capture effect based on distractor-target color similarity could be found in the second block. Results showed stimulus-driven attention capture in all blocks. In fact, the capture effect by the non-matching distractor was largest in the first block, indicating that training on the task improved distractor suppression. We conclude that successful suppression of stimulus-driven capture is impossible when the distractor is defined within the same dimension as the target.

33.409 **Attentional capture within and between depth planes** Thorsten Plewan[1](plewan@ifado.de), Gerhard Rinkenauer[1]; [1]Leibniz Research Centre for Working Environment and Human Factors

Theories of visual attention suggest two opposed control mechanisms: On the one hand there is intentional allocation of attention to specific objects or locations, or on the other hand involuntary attentional selection by salient stimulus properties. These mechanisms may also be depth-sensitive. Accordingly, attention focused on a specific depth plane would be affected by salient stimuli presented in other (unattended) depth planes. The present study investigated this issue using the additional singleton paradigm. In a first experiment, participants searched for a target displaced in depth (i.e. shifted to a closer or farther depth position). At the same time an additional but irrelevant singleton (distractor) was presented within the same or a different depth plane. This distractor could also vary in terms of color (same or different as the target). Analysis of reaction times revealed that participants responded slower in case the distractor was located within the same depth plane as the target. The color of the distractor did not further modulate reactions times. A second experiment tested whether the relative depth positions ("near" vs. "far") of target and distractor are behaviorally relevant. As previously observed, reaction times were faster when target and distractor were displayed in different depth planes. Moreover, it was evident that participants identified the target faster if it was presented in the "near" depth position, although participants were informed in which depth plane the target will appear. Taken together both experiments suggest that stereoscopic depth information can be employed to focus attention on a specific depth plane. This mechanism, however, may not be prone to distraction from other depth planes. In particular, targets in "near" position are detected faster than those displayed in "far" position, which might indicate attentional capture from unattended depth planes.

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33.410 **Attentional capture by contextual cues can cause inverse cueing effects (same location costs)** Josef G. Schönhammer[1](josef.schoenhammer@unige.ch), Stefanie I. Becker[2], Dirk Kerzel[1]; [1]University of Geneva, [2]The University of Queensland

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In contingent attentional capture, spatially irrelevant precues capture attention only when their properties match the task-set for the target properties. It is well-known that task-sets can be configured for the relative target features (e.g., redder) when target and nontarget features remain constant (e.g., an orange target and yellow nontargets; target consistently the reddest item). Provided a task-set for the relative target feature, cues only captured attention when they matched the relative target feature (e.g., a red cue among three orange contextual cues captured). Critically, target non-matching cues (e.g., a yellow cue among orange contextual cues) resulted in inverse cueing effects. That is, responses to the target were slower when the yellow cue was presented at the target location than when it was at a non-target location. In addition, lateralized occipital ERPs (which serve as markers for attention) showed a reverse effect of a positive voltage deflection in the time window of the N2pc (Schönhammer, Grubert, Kerzel, & Becker, 2016). Here, we examined these effects in more detail. According to an inhibition account, the inverse validity effect and the positivity might indicate that the non-matching yellow cue was suppressed. Alternatively, the three contextual cues might have captured attention because they were redder (e.g., than the yellow cue). To disentangle these accounts, we measured lateralized ERPs to the cue array when the non-matching cue was lateral and the contextual cue elements were presented on the vertical midline (or vice versa). When the contextual cues were lateral, we observed a substantial N2pc, suggesting that the contextual cues captured attention. Conversely, we obtained only a small positivity when the non-matching cue was lateral. Therefore, we conclude that the inverse validity effects and positive voltage deflections in our previous studies primarily reflect attentional capture by the contextual cues.

33.411 Errors without doubt: Stimulus-driven attentional capture leads to feature-binding errors but no loss in confidence

Jiageng Chen[1](chen.5805@osu.edu), Julie D Golomb[1]; [1]Department of Psychology, The Ohio State University

Spatial attention is believed to play an essential role in feature binding, with voluntary (top-down) attention demonstrating clear influences on both correct feature-binding and feature-binding errors (Golomb et al, 2014). But attention is not always voluntary—in visual processing, spatial attention can also be captured automatically by stimulus-driven (bottom-up) cues. What happens to feature perception when spatial attention is voluntarily directed to a target location, but inadvertently captured by a distractor elsewhere? Subjects were presented with four colored squares for 50ms. One item (the target) was highlighted with a white border, and subjects reported the target's color by clicking on a colorwheel. To manipulate attentional capture, a salient distractor (four white dots) could surround the target (valid trials), an adjacent item (invalid), or not appear at all (neutral). Probabilistic mixture modeling revealed that subjects' responses were less precise (higher guessing rate, larger SD) in invalid trials, with a significant increase in "swap" errors (probability of misreporting the distractor color instead of the target color). Critically, we supplemented the standard continuous-report task with a confidence report, in which subjects subsequently selected a flexible range of error around their "best-guess" on the colorwheel. In valid trials, the size of the confidence range accurately reflected performance; subjects were significantly less confident when making errors than correct responses. However, in invalid trials, subjects were equally confident when misreporting the salient distractor as when reporting the correct target color, indicating that when attention was captured by the distractor, subjects were nevertheless confident they were correctly reporting the target. Finally, even in invalid trials when the distractor was successfully ignored, we found evidence of feature-distortion errors (repulsion away from the distractor color). These results highlight the significant role of spatial attention on feature binding and reflect a unique feature-binding error pattern induced by stimulus-driven attentional capture.

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33.412 Peripheral Cueing of Attention: No Selective Attention Capture by Top-Down Matching Singleton Cues in the Presence of Top-down Matching Non-Singletons

Tobias Schoeberl[1](tobias.schoeberl@univie.ac.at), Florian Goller[1], Ulrich Ansorge[1]; [1]University of Vienna

In spatial cueing, peripheral singleton cues presented prior to the onset of a searched-for target capture attention when the cues' features match to the searched-for features of the target: Reacting to targets is faster when the matching singleton cues appear at the same location as the target compared to when the matching singleton cues appear at a different location as the target, an observation labeled the cueing effect. Importantly, when the singleton cues do not owe the searched-for features of the target (when they are top-down non-matching), cueing effects are often absent. This observation has been accommodated by bottom-up theories of attention capture by postulating 1) initial capture of attention by the salient singleton cues but 2) rapid disengagement of attention from the locations of the singleton cues if the cues do not owe the target's searched-for features. In the present study, we tested this conjecture with a novel manipulation: We presented top-down matching singleton cues (cues owing one out of two possible target colors) among top-down matching non-singletons (non-singletons which also had one of the possible target colors). If singletons received attentional priority by default and disengagement only occurred when the cues mismatched to the search settings of the observer, cueing effects should be observed with this manipulation. However, as the results showed, cueing effects were essentially absent with this manipulation, whereas regular cueing effects were observed when only the singleton cues, but not the distractors, were top-down matching. This observation is discussed in light of bottom-up theories of attention capture and of recent signal-suppression accounts.

33.413 Altering oculomotor capture by manipulating expectation breadth for a singleton color

Daniel Ernst[1](daniel.ernst@uni-bielefeld.de), Gernot Horstmann[1]; [1]Neuro-Cognitive Psychology & CITEC, Bielefeld University

While much of the literature on involuntary attention has been devoted to the conflict between Contingent Capture and Saliency Capture, a further variant has been proposed as Surprise Capture. Surprise Capture is thought as the attraction of attention instigated by expectation-discrepant, surprising, or novel stimuli. Recent eye-tracking experiments have revealed earlier and longer gaze fixations on an unexpected novel singleton color, consistent with Surprise Capture. This was tested via 32 familiarizing search trials including an irrelevant singleton with a constant color followed by a surprise trial, where the singleton color was changed. Other studies showed that the impact of surprising events on task performance varies with the discrepancy between the expected and the actual surprising event. Yet, the effect of different expectation breadths about specific display elements on gaze behavior has not been investigated. Here, we tested the effect of singleton color variations in the familiarization trials and variations of the number of familiarization trials. We predicted a weakening of Surprise Capture with more variation of the singleton colors within familiarization trials and with a lower number of familiarization trials. Results confirmed this prediction and suggested that expectations towards a singleton color become narrower with a higher number of samples and less variation within the samples. In addition, results suggested that expectation strength reached its asymptote relatively fast: After 17 familiarization trials, Surprise Capture was as strong as after 49 familiarization trials. Reducing the number of familiarization trials even more, however, resulted in a significant decrease of Surprise Capture.

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33.414 Do Top-Down Search Templates for Color Depend on Language?

Diane Baier[1](diane.baier@univie.ac.at), Ulrich Ansorge[1]; [1]University of Vienna (Faculty of Psychology, Department of Basic Psychological Research and Research Methods)

Here, I investigated if color search in the contingent-capture protocol could be based on verbal or semantic top-down templates. I compared search efficiency for color and color-word stimuli in five experiments. As is typical for the contingent-capture protocol, validity effects (shorter search times and fewer errors for validly than invalidly cued targets) were only found for color cues that matched the top-down search templates. In addition, I compared contingent-capture effects of color cues and color-word cues during top-down search for a color target (Experiment 1), a color-word target (Experiment 2), and both color and color-word targets (Experiment 3). Only cues of the same stimulus category as the target (either color cues or color-word cues) captured attention. This makes it unlikely that color search is based on verbal or semantic search templates. These results also argue for stimulus based rather than language based priming effects during search for color-word targets. To look into the role of visual features for these priming effects, I compared color-word cues of matching and non-matching fonts preceding color-word targets in Experiment 4. The cues captured attention regardless of whether the cue font matched the target font. This makes it unlikely that font-based priming accounted for the word cueing effects. In Experiment 5, I investigated the possibility of phonological priming. Participants executed the experiment (color-word cues before color-word targets) while repeating syllables (articulatory suppression) or not. Articulatory suppression had no influence, hence, phonological priming is also unlikely. Together, the results speak for an abstract orthographic nature of cue-based priming during color-word search and show that verbal or semantic search templates do not play a role in contingent-capture by color.

33.415 **Search efficiency is not enough; the nature of search task modulates attentional capture by a salient distractor in inefficient visual search** Koeun Jung[1](jungke1225@gmail.com), Suk Won Han[1], Yoonki Min[1]; [1]Department of Psychology, Chungnam Natioal University

Recent studies about attentional capture reported that the capture of attention by a singleton distractor increased when search efficiency decreased. Expanding these studies, we tested whether search efficiency manipulation has similar effect on stimulus-driven attentional capture across different types of search tasks. In our experiment, twenty undergraduates performed two different types of visual search tasks, including a single target and eight distractors. For one, participants searched for a right- or left-tilted line among vertical lines (orientation feature search). For the other, participants looked for an outlined square with a right- or left-gap among squares with a top- or bottom-gap (Landolt C search). For each search task, we had two different levels of search difficulty (easy vs. difficult); For the feature search task, the tilt of the target was either 4.5 (difficult) or 9 degree (easy). For the Landolt-C search, the size of gap was set to either 3 or 6 degree. A half of the total trials had a distinct color distractor and these trials are referred to as distractor-present trials. In the remaining trials, there was no singleton distractor (distractor-absent). As results, under feature search, attentional capture by the color singleton was found, $p < .001$. This capture significantly increased when the similarity between the target and distractor decreased, $p < .05$, replicating previous findings. Under the Landolt-C search, no attentional capture was found, $p > .47$. Importantly, both the easy and difficult Landolt-C search tasks yielded more robust set-size effect and longer RT than the easy feature search. These results indicate that search difficulty or efficiency cannot fully explain the capture of attention by a salient stimulus. The present findings suggest that the process of searching for the Landolt target involves qualitatively different process than the feature search, pointing to the role of search demand on attentional capture.

33.416 **Set size matters when capturing attention in a hybrid visual-memory search** Katherine S Moore[1](moorek@arcadia.edu), Jaimie Jasina[1], Ariel Kershner[1], Aziza Ransome[1]; [1]Arcadia University

In a hybrid visual-memory search, increasing the number of concurrently searched for targets (i.e. "memory" set size) has a logarithmic effect on slowing search speed. Visual search is also impaired by the presence of distractors that resemble targets, a phenomenon called contingent attentional capture (e.g., it is harder to find a particular "camera," when a different camera appears). Set-specific capture, a more dramatic distraction cost, occurs when the presence of a goal-related distractor (e.g. the wrong camera) causes an internal shift of attention to the related goal state ("camera"), away from other search goals (e.g. "laptop"). Though we understand how visual search speeds are modulated by the memory set size, it is not clear how or whether distraction is affected by set size. In the present study, we investigated whether attentional capture and set-specific capture are modulated by the number of concurrently maintained search goals. Participants memorized a set of target objects, and then searched a rapid serial visual presentation for the memorized objects. On some trials, a distractor appeared 1-2 frames prior to a target object, and the distractor was either from the same object category as the target (measuring contingent attentional capture) or a different object category as the target (measuring set-specific capture). Participants completed the task for set sizes 2, 4, and 16. Display speed was calibrated to maintain uniform accuracy across participants and set sizes. Replicating other hybrid visual-memory search results, search speed increased logarithmically with memory set size. Contingent attentional capture effects were greatest at larger set sizes, whereas set-specific capture effects were greatest at smaller set sizes. This finding supports the notion that these phenomena represent distinct mechanisms. It also speaks to how search goals are maintained and used in a visual-memory hybrid search, as well as what occurs during distraction.

33.417 **Saliency capture, contingent capture and onset capture in visual search and spatial cueing** Stefanie I. Becker[1](s.becker@psy.uq.edu.au), Courtney Judd[1]; [1]School of Psychology, The University of Queensland, Brisbane, Australia.

Visual attention can be reflexively drawn to salient stimuli (saliency capture), sudden onsets (onset capture), or stimuli that are similar to a sought-after target (contingent capture). However, previous studies showed that a salient distractor can affect attention very differently depending on whether its effects are measured in the visual search paradigm or the spatial cueing paradigm. In the present study, we compared the effects of different distractors in both tasks (visual search, spatial cueing), to ascertain whether different forms of attentional capture (saliency capture, onset capture and contingent capture) are indeed related across these paradigms. In the visual search task, we monitored participant's eye movements in response to a salient red or green distractor, an onset distractor, or a target-similar distractor in search for a shape target. In the spatial cueing paradigm, we assessed validity effects to the same stimuli when the distractor (cue) was briefly presented prior to the target display. The results showed strong capture effects for the onset and target-similar distractor across both paradigms, but only weak effects of salient colour distractors. In visual search, capture scores derived from eye movement parameters were much more reliable than other measures (e.g., RT). Still, there were significant correlations in capture for all distractors across paradigms. Overall, target-similar distractors captured attention most reliably and correlated most strongly across paradigms. Performance in visual search also correlated with intelligence (g), though this was mainly limited to the ability to quickly select the target. Overall, the results indicate that the two paradigms tap into the same constructs of attentional capture, which are however difficult to measure with a high degree of reliability. Moreover, capture by salient items or sudden onsets are probably not related to a weak top-down control mechanism, as contingent capture and onset/saliency capture were not inversely related to each other.

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33.418 **Suppression of Attention Capture: The Role of Selection History** Nicholas Gaspelin[1](ngaspelin@ucdavis.edu), John M Gaspar[2], Steven J Luck[2]; [1]Department of Psychology, Binghamton University, State University of New York, [2]Center for Mind and Brain, University of California, Davis

Researchers have long debated whether salient objects can involuntarily capture attention. We recently discovered a new lead: There seems to be a key role of inhibition in the avoidance of attention capture by salient objects. This suppression model has been supported by converging evidence from behavioral, eye tracking, and electrophysiological studies. However, the precise nature of the mechanism underlying these suppression effects is unclear. A large line of research suggests that factors such as scene context or implicit knowledge about the previous trial can play a surprisingly large role in the size of observed capture effects (called selection history). In the current talk, we explore the role of selection history in the suppression of salient items.

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33.419 **Working memory prioritization impacts the dynamics of attentional capture** Remington Mallett[1](remym@utexas.edu), Jarrod A. Lewis-Peacock[1]; [1]University of Texas at Austin, Department of Psychology

Sunday AM

Working memory representations bias visual experience by drawing attention to matching stimuli in the environment (i.e., "attentional capture"). This finding is reliable when a single item is held in memory, yet it is unclear how attentional capture is impacted under increased memory loads. Here, we characterized how two items in working memory—one in a high-priority state and another in a low-priority state—biased visual attention. We implemented a double retro-cue task involving two consecutive memory delay periods within each trial. In the first delay, one memory item was cued as relevant for the first probe. This tagged that item as high-priority, simultaneously tagging the other (uncued) memory item as low-priority. A cue before the second delay indicated which item would be tested by the final probe of the trial. During both delays, subjects performed a sequence of visual search trials that manipulated the possibility of exogenous attentional biases via reappearance/absence of memory items. The systematic variation of these search trials allowed us to decode the identity of memory items with pattern classifiers applied to RTs from the delay (Dowd et al., 2017). High-priority items were decodable and showed persistent attentional capture throughout the search task (~ 12 sec). In contrast, low-priority items were not decodable and further analyses showed that these items biased attention early but briefly (~ 3 sec). During the second delay, where the previously uncued (low-priority) item was cued as relevant on half of trials, the attentional capture effect on visual attention returned. The lack of consistent visual attentional bias from a low-priority representation in working memory is consistent with theoretical models of attentional templates (Olivers et al., 2011). Our findings demonstrate that attentional capture is a transient effect that depends on the priority and, by inference, the representational state of items held in working memory.

33.420 **Attentional capture by redundant visual information** Jiyeong Ha[1](jiyeongha@yonsei.ac.kr), Hee-kyung Park[1], Yoonjung Lee[1], Do-Joon Yi[1]; [1]Department of Psychology, Yonsei University

Visual environments we encounter in our daily life are full of perceptually and conceptually similar information. Thus, understanding how the visual system detects and summarizes redundant information provides clues to the mechanisms in which our minds interact with the environment. According to previous studies (Jiang et al., 2010; Won & Jiang, 2013), visual redundancy enhances the quality of perception and memory representations. Also, we have demonstrated that redundant distractors capture attention in a name-face Stroop task (Lee et al., 2014). In the current experiment, we extended our previous study using object stimuli and a drift diffusion modeling. Participants decided whether a target word at fixation belonged to fruit or clothes. Distractors were the pictures of fruit or clothes, and they could interfere with target responses. The distractor stimuli were from either the same or different category of the target (Congruent vs. Incongruent), and one either on the left or right side or two identical items on the both sides of the target appeared (Single vs. Redundant). We replicated our results that congruency effects in RT were greater in the redundant than the single condition. Specifically, the incongruent/redundant condition produced slower RTs than the incongruent/single condition. In order to understand the underlying mechanism of our results, we fitted the drift diffusion model to the two incongruent conditions using a hierarchical Bayesian estimation technique implemented in 'hBayesDM' package (Ahn, Haines, & Zhang, 2017). Comparing the posterior distributions of hyper-parameters revealed that only β (bias) was significantly increased in the redudant distractor condition relative to the single distractor condition. On the other hand, α (boundary separation), δ (drift rate), τ (non-decision time) were less affected by distractor redundancy. Based on these findings, we conclude that attentional capture triggered by visual redundancy takes place at the early stage where perceptual evidence is built up.

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33.421 **The Attentional "White Bear" Evades Visual Working Memory** Ryan S Williams[1](ryanscott.williams@mail.utoronto.ca), Robert Newman[1], Jay Pratt[1], Susanne Ferber[1]; [1]Department of Psychology, University of Toronto

In visual search, cueing a feature (e.g., color) of a to-be-ignored item typically offers no attentional advantage and sometimes interferes with task performance. Since resource allocation models contend that the resolution of visual working memory (VWM) representations is determined by the distribution of attention across items, we sought to investigate the effect of featurally cueing task-irrelevant items on VWM. In Experiment 1, participants were presented displays of isoluminant diamonds that varied in hue and were to indicate the location of a "chip" that was present on the top or bottom of one of the diamonds. Prior to target presentation, a cue indicated the color of one non-target diamond that could be ignored (Ignore condition), or provided no such information (Neutral condition). Our results suggested that participants were unable to suppress attention to the cued items; performance was equal for both conditions. Experiment 2 employed a similar cueing procedure, but with a delayed estimation task. Participants studied displays of briefly presented colored squares then reported the color of one probed item following a 900 ms delay. Critically, ignore and neutral cues were presented before study displays. After decomposing response errors into a three-parameter mixture model, we found that participants held more precise representations of studied items in the Ignore compared to the Neutral condition. Experiment 3 again used the delayed estimation task, but now intermixed delays of 300 ms and 1500 ms to determine if the cueing benefit occurred at encoding or during maintenance. Again, we found precision to be higher in the Ignore condition regardless of delay length. These findings suggest that while cueing features of task irrelevant items is not sufficient to suppress attention to these items, such cues do benefit the encoding of task-relevant items.

33.422 **The Power of Negative Thinking: Paradoxical but Effective Ignoring of Salient-but-Irrelevant Stimuli by a Spatial Cue** Seah Chang[1](seahchang@jhu.edu), Corbin A. Cunningham[1], Howard E. Egeth[1]; [1]Department of Psychological & Brain Sciences, Johns Hopkins University

It is often assumed that a uniquely colored singleton among other uniformly colored stimuli can function as a powerful attractor of attention (Theeuwes, 1992). However, top-down attentional mechanisms are also powerful and can suppress distractors when a pre-cue is given (Cunningham & Egeth, 2016; Munneke, Van der Stigchel, & Theeuwes, 2008). The current study tested whether an endogenous spatial cue indicating the location of a salient color singleton distractor can eliminate involuntary attentional allocation to such a stimulus. On each trial, either a capital "B" or "F" was randomly presented as the target letter. On ignore trials, an arrow cue indicated a to-be-ignored location that would never contain a target but would contain a color singleton distractor. Neutral trials provided no useful spatial information. Target-distractor compatibility was manipulated with a lowercase 'b' or 'f' distractor to test processing of the cued location. The results showed that a significant singleton capture effect was eliminated on ignore trials regardless of the consistency of the singleton color (Experiments 1 & 2). Significant compatibility effects were observed on both ignore and neutral trials, suggesting that participants adopted the strategy of selecting the cued location followed by rapid disengagement from that location on ignore trials. Overall, a spatial cue produces paradoxical but effective ignoring of salient-but-irrelevant stimuli; with a spatial cue, participants inhibited a cued location by first selecting the location and then rapidly disengaging from it. To explore whether participants could learn to ignore the color singleton in the absence of a spatial cue (Gaspelin & Luck, 2017; Vatterott & Vecera, 2012), in Experiment 3, only neutral trials were used with a consistent color singleton. Participants were not able to suppress singleton distractors, although the magnitude of singleton capture effects was reduced compared to that of neutral trials in Experiments 1 and 2.

33.423 **Whereof one cannot speak: How language and capture of visual attention interact** Florian Goller[1](florian.goller@univie.ac.at), Soonja Choi[1,2], Ulrich Ansorge[1]; [1]University of Vienna, [2]San Diego State University

Using a contingent capture paradigm, we examined not only whether but also how deeply language influences visual perception. We tested native speakers of Korean and German, two languages that semantically categorize spatial relations in fundamentally different ways: German (similar to English) categorizes spatial relations based on containment (in) and support (auf), whereas Korean categorizes by – and thus semantically distinguish between - tight-fit (kkita) vs. loose-fit (nehta, nohta). We investigated whether participants' native language makes them more or less sensitive to features of visual stimuli that resemble tight-fit or loose-fit. We let Korean and German speakers search for a predefined

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colour target among distractors. Unbeknownst to the participants, targets were also implicitly signalled by features of a different sematic domain, i.e. spatial relations of tight-fit or loose-fit. We found that only Koreans spontaneously picked up on this implicit feature of spatial fitness (tight-fit or loose-fit) and used it to aid their search for targets. As these spatial concepts are not grammticalised in the German language, our results demonstrate that there is an influence of language-specific semantics of the native language on very basic processes of visual attention.

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33.424 **Reaching behavior reveals outsized impact of distractor salience and selection history in young children** Jeff Moher[1](-jmoher@conncoll.edu), Christopher D Erb[2], Stuart Marcovitch[2]; [1]Psychology Department, Connecticut College, [2]Department of Psychology, University of North Carolina, Greensboro

Recent methodological advances have enabled researchers to explore the dynamics of attentional control and distractibility by recording the spatial and temporal dynamics of hand movements. Although this approach has proven insightful for studying attention in adults, less research has employed these techniques to study the development of attention. Here, we address this gap in the literature by using reach tracking to measure attention capture in 5-year-olds, 9-year-olds, 13-14-year-olds, and adults. We instructed participants to touch a target (a diamond) that appeared on a display alongside three non-targets (circles). On half of the trials, all objects were the same color. On the remaining half, one of the circles was uniquely colored, providing a salient distractor. Consistent with previous work with adults, reach trajectories were attracted toward the location of the distractor. The size of this attraction did not significantly vary across age groups. However, distractor-related costs in movement time (MT: time elapsed between hand movement onset and offset) did differ across age groups. MT was slowed by the presence of a distractor in 5-year-olds (42 ms slower) and 9-year-olds (12 ms), but not in older age groups. MT costs were largely incurred during the early portion of the movement, and accompanied by decrements in velocity, suggesting that salient distractors produced cautious or uncertain initial movements in young children. Location repetition effects revealed a similar developmental trajectory, with larger repetition effects across multiple measures in 5-year-olds compared to older ages. These results demonstrate that younger children, in comparison to older children and adults, are strongly influenced by distractions and other task-irrelevant factors during goal-directed action. The visually-guided reaching approach allowed us to examine the time-course of these issues, revealing dissociations in which some components of goal-directed actions change over the course of development, while others remain consistent.

Attention: Resources divided and suppressed

Sunday, May 20, 8:30 am - 12:30 pm, Pavilion

33.425 **ERP measures of target and distractor processing are affected by attentional prioritization** Christine Salahub[1](cs13aj@brocku.ca), Blaire Dube[2], Naseem Al-Aidroos[2], Stephen M. Emrich[1]; [1]Brock University, [2]University of Guelph

When faced with relevant and irrelevant information, attention can act as a "bouncer in brain", letting in important information while filtering out distractors. However, when all items are relevant, attention may also act as a dial, adjusting the relative priority of each item. For example, it has been demonstrated using feature based attention that the more importance placed upon an item, the more precisely it is encoded into working memory (WM). However, it is unknown whether this attentional prioritization reflects target enhancement, distractor suppression, or both. In the current study, we examined whether manipulating the attentional prioritization of one shape over another (i.e., circles versus squares) would affect event-related potentials of target and distractor processing: the distractor positivity (Pd) and the target negativity (Nt). Participants completed a visual WM task for two coloured shapes, and the likelihood that one shape would be probed over the other was manipulated. In the 100% likelihood blocks, participants could either be presented with two target shapes (50% attentional allocation to each shape), or one target and one distractor (100% prioritization of the target), while in the remaining blocks one item was probed 75% of the time. It was found that the Pd and Nt were influenced by attentional prioritization, such that greater distractor suppression was present when the target was prioritized 100% of the time, versus 75 or 50%. We also found the SPCN was affected by attentional prioritization, suggesting differences in WM consolidation as a function of attentional prioritization. Finally, behavioral results suggested that memory performance is associated with the degree to which items were processed as targets or distractors. Thus, neural measures associated with target and distractor processing may reflect the degree to which attention prioritizes items in a multi target array, in addition to reflecting a filtering mechanism.

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33.426 **A Binding Illusion of Ambiguous Color Location Between Two Locations** Cristina R Ceja[1](crceja@u.northwestern.edu), Steven L Franconeri[1]; [1]Northwestern University

Attention is required for integrating some combinations of object features, such as color and spatial location (Luck & Beach, 1998). Previous research has shown that features can be incorrectly bound, forming illusory conjunctions of features, when attention is diverted or overloaded (Treisman & Schmidt, 1982). Here we present a new illusory conjunction illusion, using even simpler stimulus displays. As a distracting task, participants were shown three shapes on each side of the screen and asked to report whether the objects were all the same shape (i.e., all squares) or different shapes (i.e., a combination of squares and circles). The center of each display contained four gray diamonds displayed horizontally, and two of the diamonds quickly flashed as two colors (i.e., both green, both red, or one green and one red; 80ms) in each trial. Participants were asked to also report whether the colors were the same (i.e., both red or both green) or whether the colors were different (i.e., one red and one green). Afterward, participants were asked to report whether they observed ambiguity in the location of the colored diamonds (i.e., if they could locate which of the diamonds changed colors in the display). When participants responded correctly to trials in which the colors were different, they reported ambiguity in the location of the colored stimuli 40% of the time, on average. Although participants were able to accurately perceive the objects' colors, they systematically failed to bind those colors to their respective locations.

33.427 **Perceptual as well as conceptual similarity factors drive competitive relations among irrelevant visual distractors** Nurit Gronau[1](nuritgro@openu.ac.il), Hanna Benoni[1,2], Anna Izoutcheev[1]; [1]Open University of Israel, [2]College of Management

During a brief visual glance, multiple stimuli often compete for representation, leading to degraded encoding of stimuli's identities, particularly when these appear outside the focus of visual attention. Similarity among stimuli plays an important role in competition, as reduced encoding precision is typically observed with increased stimulus similarity. Similarity, however, can be perceived or judged according to different stimulus properties and at different processing levels - a featural (low) or a conceptual (high) level of representation. The present study tried to tease apart perceptual from conceptual (e.g., categorical) similarity factors, by holding constant each of these dimensions while assessing their unique contribution to stimulus competition. Using a "dilution" paradigm, we measured the extent to which neutral stimuli diluted (i.e., attenuated or eliminated) distractor interference effects in a flanker task, as a function of diluter-distractor similarity. Target and distractor were both composed of digital letters (H,T), while diluter stimuli were selected from one of two conceptual categories - letters or digits. Critically, the diluters were identical in their low-level features across both categories (e.g., the digital letter E vs. the "mirrored" digital number 3, digital P vs. digital 9, etc.). When holding constant category and manipulating diluters' visual appearance, a rather robust perceptual manipulation (color) was required to reduce diluter-distractor competition. However, when controlling for perceptual similarity, a significantly larger dilution effect (indicating competition) was observed among the letter- than the digit-diluter condition, suggesting an additional strong inter-category source of competition. This latter effect, however, was obtained only when the different categories were presented in separate blocks, not when mixed within the same block. Taken together, our findings suggest that competition occurs at both featural and categorical levels, yet processing unattended categorical information (i.e., of diluter stimuli) may strongly rely on continuous task-related strategies, expectancies, and/or recent experience (e.g., trial-to-trial priming).

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33.428 **Suppression history of spatial locations biases attentional and oculomotor control** Valeria Di Caro[1](valeria.dicaro@univr.it), Jan Theeuwes[2], Chiara Della Libera[1]; [1]Department of Neurosciences Biomedicine and Movement Sciences, University of Verona, [2]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam

The ability to attend to what is relevant in our visual field requires to overcome the interference exerted by salient-but irrelevant stimuli. Attentional processing can be shaped by experience gained in the past, so that statistical regularities and learned associations can influence attentional selection, by enhancing the processing of stimuli and locations frequently associated with task-relevant information. The present study investigated how attentional and oculomotor capture can be influenced by learned statistical regularities, focusing in particular on the spatial probability of salient but irrelevant distractors. For this purpose, we used a variant of the additional singleton paradigm in which participants had to attend to a colour singleton target, within a visual array of 6 items. Unbeknown to participants, in a predefined proportion of trials, a salient onset distractor was also presented in the display, appearing with different probabilities in one of six possible locations: 2 locations were occupied by the salient onset with High Frequency (HF; 76% of the distractor present trials), while the remaining 4 were occupied by the salient onset with an overall Low Frequency (LF; 24%). Both manual response times and eye-movements were recorded. We found that although manual RTs were significantly slower in distractor present trials, this interference was strongly modulated by distractor location, showing a reduced performance cost when the distractor appeared at HF locations. Consistently, distractors in HF locations led to less powerful oculomotor capture compared to those appearing at LF locations and, under these conditions, the first saccades were more often directed toward the target. These findings suggest that the statistical spatial regularities associated with the attentional filtering of salient distractors modulate attentional and oculomotor performance, reducing the attentional priority of spatial locations that have been systematically associated with distracting events.

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33.429 **Fatigue causes lengthened giving-up times when the task is hard** Gemma L Hanson[1](g.hanson@soton.ac.uk), Dominic Taunton[2], Tamaryn Menneer[1], Nicholas Donnelly[1]; [1]Psychology, University of Southampton, UK, [2]Southampton Marine and Maritime Institute, University of Southampton, UK

Negative effects of partial or acute sleep-deprivation on attention and working-memory are well established (Alhola & Plo-Kantola, 2007). In the present study fatigue was explored in the context of a word-generation task, providing an understanding of whether fatigue affects the behavioural style of the task or the way in which it is processed. The current study compared performance across two word-generation tasks across participants whose sleep was restricted to 4 hours for 3 consecutive nights, whose sleep was deprived for 30 hours and participants who maintained their usual sleep. Participants were presented with two sets of seven letters, one set was deemed easy while the other hard. From these two lettersets they generated as many words as possible (Payne et al., 2007). Only one set of letters was visible at a given time, and participants could freely switch between them. Karolinska Sleepiness Scale (Åkerstedt & Gillberg, 1990) ratings were highest for the sleep-deprived group, followed by the sleep-restricted then controls. Fatigue was associated with a reduction in the number of words generated, and an increase in the time from the last word generated to switching to the other letter set (giving-up time), but only when the task was hard. A possible explanation might be the rate that they generated words changed. This was calculated by dividing the time before giving up by the number of words generated which provided an index of the rate of word generation; this did not change with fatigue. An alternative explanation is that the results may be related to an impaired ability to recall words. The frequency of words generated was explored; it was not affected by fatigue. The present study therefore suggested that following fatigue, the nature of how you perform the task doesn't change it simply causes participants to take longer to give-up.

Acknowledgement: TK foundation's MARTHA Project and Leverhulme Trust

33.430 **Evaluation of visual sensitivity across the visual field under varying levels of cognitive load** Simona Buetti[1](buetti@illinois.edu), Sophie I Leib[2]; [1]Department of Psychology, LAS, University of Illinois, [2]Department of Psychology, Rosalind Franklin University of Medicine and Science

Buetti and Lleras (2016) demonstrated that the level of engagement required by a cognitive task modulates the rate of oculomotor capture by task-irrelevant images. Specifically, oculomotor capture diminished from ~70% to ~40% when participants performed a series of easy mental math operations compared to a series of difficult mental math operations. An advantage of the task used by Buetti and Lleras is that the task did not constrain in any way visual attention: math operations were presented auditorily and the images that appeared on the display were the only visual events in the trial sequence (and were completely unrelated to the task). Buetti and Lleras suggested that when attention is required internally by a cognitive task there is an automatic tuning down of external sensory information. The goal of the present study was to seek a more direct measure of this reduction in visual sensitivity under different cognitive load conditions. Visual sensitivity was examined using the Octopus 900 visual perimeter taking advantage of the wide presentation field and the adaptive stair-casing. Sixty locations throughout the visual field were examined using 100 ms flashes of varying intensity. Participants completed the visual detection task under three conditions: 1) baseline (detection task only); 2) low load (series of simple mental math operations presented auditorily in addition to the detection task); 3) high load (series of more difficult mental math operations in addition to the detection task). The results showed the expected decrease in visual sensitivity as a function eccentricity as well as an additive effect of cognitive load. Interestingly, there was no significant interaction, suggesting that sensitivity throughout the visual field was equally affected. The results are discussed in relation to the literatures on the useful field of view and Inattentional Blindness, and a possible neural underlying mechanism is presented.

33.431 **Reconceptualizing perceptual load as a rate problem: The role of time in the allocation of selective attention** Zhi Li[1](zli1@zju.edu.cn), Keyun Xin[1], Wei Li[1], Yanzhe Li[1]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University

The load theory of selective attention proposed that it is the perceptual load of a task that determines the allocation of selective attention. Task-irrelevant information will be identified when perceptual load is low, but not when it is high. However, load theory has not provided clear definition of what perceptual load is. In practice, load studies often associated perceptual load of a task to the quantity of information contained in that task. That is, the information load is often considered as the perceptual load. In the present study, we suggested that, rather than conceiving of perceptual load as a quantity of information, we should consider it as a quantity of information per unit of time. That is, it is the relationship between the information load of a task and the time available for processing the information that determines the allocation of selective attention. Two experiments were conducted to support this idea. Experiment 1 showed, using a classic load study paradigm, that when information load was held constant, the extent of the distractor interference varied with the stimulus exposure duration. Experiment 2 showed, using a new paradigm, that when the information load changed, the extent of distractor interference can still be held constant by adjusting the stimulus exposure duration. These findings supported and extended the load theory, allowing it to explain findings that were previously considered as counter evidence of load theory.

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33.432 **Competition for attentional selection between reward and loss value associations** Jaclyn Dell[1](jdell1@mail.usf.edu), Melissa Cloutier[1], Heather Crews[1], Brianna Suite[1], Andrea Veramendi[1], Jennifer L. O'Brien[1]; [1]Department of Psychology, University of South Florida St. Petersburg

Efficacy of attentional selection in visual search is known to be rapidly modulated by the expected reward values associated with stimuli within an array. Neurophysiological evidence for increased attentional capture by high-valued stimuli has been found in the mean amplitude of the N2pc and PD, EEG components thought to reflect attentional target selection processes and suppression of attention to distractors, respectively. Visual search is enhanced with reward-associated targets in search arrays. The N2pc has been shown to be larger in amplitude for high- than low-reward targets, reflecting easier search due to larger attentional prioritization of high-valued stimuli. In contrast, reward-associated distractors in search arrays cause search costs. High-reward distractors elicit a reduced N2pc and larger PD, reflecting less effective distractor suppression. However, it is unclear whether prioritization of reward-associated stimuli persists when presented simultaneously with loss-associated stimuli. To test this, we first had participants engage in a simple choice task where they gained or lost money with high or low probability in response to choosing specific visual stimuli. After learning, value associated stimuli appeared as targets among novel distractors and, on some trials, a singleton value-associated distractor in 4-item visual search arrays (two on horizontal midline, two on vertical, on either side of fixation). Target-distractor pairings were constrained such that they were of opposite valence (one gain, one loss) and never appeared on the same midline. ERP results show a larger N2pc to reward-associated targets on the horizontal midline (with loss-associated distractor on vertical) than to loss-associated targets (with gain-associated distractor on vertical), most prominent when the target was previously paired with a high probability reward. Reward-associated stimuli appear to capture more attention over loss-associated distractors when competing for attention.

33.433 **Scarcity biases attention to motivationally relevant distractors** Brandon M 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

Individuals experiencing resource scarcity often demonstrate cognitive and behavioral impairments that can further perpetuate scarcity. Here we examine an attentional mechanism to explain these impairments under scarcity. In an eyetracking experiment (N=210), participants were randomly assigned with a time budget (5 minutes in the poor condition, 20 minutes in the rich condition) to complete a set of Raven's Progressive Matrices and earn as many points as possible. In each trial, one matrix was presented in the center of the screen, and the time remaining and the current trial number were displayed in the periphery. To measure attention, we tracked gaze dwell time and fixations throughout the experiment. Consistent with previous findings, participants in the poor condition had a lower accuracy on Raven's Matrices than those in the rich condition, demonstrating cognitive impairment under scarcity. Importantly, we found that participants in the rich condition spent proportionally longer dwell time on the Raven's Matrices per trial than the poor participants, showing enhanced attentional focus on the task. On the other hand, the poor participants spent proportionally longer dwell time on the current trial number and the time remaining in the periphery. Their eye gaze also showed greater deviations from the matrix at the center. These results suggest that the poor participants spent less time on the focal task, and instead attended to motivationally relevant distractors such as the time remaining and the current trial number in order to keep track of their progress within a limited time budget. The current study provides a new attentional account for the cognitive impairments and counterproductive behaviors under scarcity. Specifically, scarcity draws attention away from the focal task to peripheral distractors that depict the amount of resources available. These findings have important implications for interventions to alleviate the cognitive tax of scarcity.

33.434 **Social presence and multimodal presentation of attentional cues: possible moderators of the Stroop effect** Anika L Gearhart[1](anikag@hawaii.edu), Basil Wahn[2], Scott Sinnett[1]; [1]Department of Psychology, University of Hawaii at Manoa, [2]Institute of Cognitive Science, University of Osnabrück

The Stroop effect, in which automatic processing of semantic information interferes with color naming, is a well-documented psychological phenomenon. However, despite the abundance of research on the task, it is unclear how the Stroop interference effect may be moderated when presenting stimuli in other sensory modalities, or by different social factors. It is clear that the vast majority of research involving the Stroop effect has involved visual presentations, however a vast and growing literature demonstrates that multimodal presentations can reduce task difficulty, and in theory should lead to improved processing in the Stroop task. In other relevant research, the introduction of a social actor in a visual-tactile interference task reduced this congruency effect, to the extent that the presence of the social actor was a more effective moderator on performance than modality (Heed, Habets, Sebanz, Knoblich, 2010). The present research extends these findings by exploring a) how a visual-auditory Stroop task differs in interference strength from a visual only Stoop, and b) how the presence of a social actor performing a task might moderate the Stroop effect seen in both the unimodal and multimodal version of the Stroop task. Participants were divided into four conditions: visual Stroop alone or with a partner and visual-auditory Stroop alone or with a partner. The partner in both tasks was a confederate and performed an unrelated task at the same computer as the target participant. Results indicate a main effect for both partner and modality but no interaction effect, suggesting that both social presence of a partner and the presentation of stimuli in multiple modalities may reduce the interference caused by the automatic processing of irrelevant cues. This may be a result of either social facilitation (Huguet, Galvaing, Monteil & Dumas, 1999) or attentional cueing, respectively.

33.435 **Walk the line: Pedestrian distraction and cross walk safety** Bonnie Angelone[1](angelone@rowan.edu), Megan Brown[1], Emily Diana[1]; [1]Department of Psychology, College of Science and Mathematics, Rowan University

While the bulk of research on cell phone distraction has focused on driving, there is more recent interest regarding walking and pedestrian safety. Over the past decade, there has been an increase in emergency room visits following pedestrian-related injury. Some researchers have used virtual reality or simulations to examine distracted walking, however, there are fewer observational studies focused on distracted walking as it occurs in a real-life setting. Pedestrians are at more risk for injury when they text, talk, converse with others, and use headphones. Cell phone users walk slower, change direction more often, and show fewer acknowledgements of others in their pathway. We conducted an observational study at three high volume crosswalks on a college campus. Pedestrians' (N=265) safety behaviors were recorded along with several common distractive behaviors. Chi-square analyses revealed that cell phone users were no different than individuals not using their phones in three observed safety behaviors: pressing/waiting for the crossing signal, looking both ways before entering crosswalks, waiting for traffic to stop before crossing. Also, individuals using headphones were no different than individuals not using headphones in the three safety behaviors. However, people who walked individually, were less likely to press the signal or wait for the cross signal than those who walked in with others. They were also more likely to look both ways before crossing. Overall, pedestrians were not engaged in a high rate of cell phone use while walking, which is promising. Also, when they did engage with their cell phones or had headphones in use, they did not display higher rates of unsafe crossing behaviors, but this was different when they walked with others. It may be the case that pedestrians use caution when approaching some crosswalks and may have adapted ways to minimally use their devices and exhibit "safe-enough" crossing behaviors.

33.436 **Effects of simulated vision impairment and auditory distraction on the detection of hazards while driving** Ting Zhang[1,2](tingzhang20@neco.edu), Steven W Savage[1], Alex R Bowers[1]; [1]Schepens Eye Research Institute, MEEI, Harvard Medical School, [2]New England College of Optometry (NECO)

Sunday AM

Being able to divide attention across different tasks when driving, such as controlling speed and lane position, searching for hazards as well as listening to commands from in-vehicle assistance systems relies on timely allocation of cognitive resources. People with impaired vision (VI e.g., visual acuity as low as 20/200) may drive on a restricted license in some states and are likely to use driver assistance systems. However, the effects and interaction of VI and auditory distraction on the detection of hazards have not previously been examined. To address this gap in the literature, the current study evaluated the effects of simulated VI and auditory distraction on the detection of pedestrians in a driving simulator. Central vision loss was simulated in young normally-sighted subjects by goggles with diffusing filters that degraded both visual acuity (20/90 with and 20/20 without goggles) and contrast sensitivity (1.44 with and 1.77 log units without goggles). Auditory task demand was manipulated by playing audiobook excerpts and instructing subjects to listen for and repeat out loud two predetermined words. Subjects completed 4 highway drives (60 mph) in counterbalanced order (1) without simulated VI and without distraction; (2) with simulated VI and without distraction, (3) without simulated VI and with distraction; and (4) with simulated VI and with distraction. Subjects pressed the horn each time they saw a pedestrian hazard. Neither simulated VI nor distraction affected detection rates. However simulated VI substantially increased RTs by around 600ms. With the addition of audio distraction, RTs increased further and detection timeliness (detected in time to avoid a collision) decreased to only 70%. Combined simulated VI and distraction substantially increased the likelihood of a potential collision in young drivers. In the next phase of the project we will recruit older drivers to test the interactions between age, simulated VI and distraction.

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33.437 **Musical expertise modulates the cost of crossmodal divided attention between vision and audition in behavior but not in tonic pupil dilation** Hiu Mei Chow[1](dorischm@gmail.com), Vivian Ciaramitaro[1]; [1]Psychology Department, University of Massachusetts, Boston

Dividing attention across sensory modalities has been shown to impair performance (e.g. Ciaramitaro et al., 2017), suggesting attention is a limited resource shared across the senses. Musical training often involves the flexible use of two or more senses concurrently (e.g. reading musical scores and listening to sounds) and has been shown to reduce the cost of unimodal dual-task performance (Moradzadeh et al., 2015). Yet, little is known regarding how musical experience might reduce the cost of crossmodal divided attention. Here we compared the cost of crossmodal divided attention in a dual-task in musicians and non-musicians combining psychophysics and pupillometry. 15 amateur musicians (8F, 10+ years of musical training) and 17 non-musicians (10F, 0-5 years of musical training) participated. Each trial contained two intervals, each with a binaural white noise sound and a RSVP of letters at fixation. A Tobii eye tracker was used to monitor eye position and pupil diameter. Participants reported which interval contained an amplitude-modulated sound, with modulation depth varying across trials. Concurrently, participants reported either, in the easy visual condition, which interval contained white letters (color detection), or in the hard visual condition, which interval contained more 'A's (quantity discrimination). We compared visual task accuracy, auditory thresholds, and mean baseline pupil dilation (-500 to 0ms relative to stimulus onset) across easy and hard conditions, to quantify the cost of crossmodal divided attention. We expected a smaller cost on auditory performance from attending a harder versus easier visual task in musicians compared to non-musicians. We found a smaller cost for musicians compared to non-musicians, as expected, but only in male, and not female participants. We found no difference in baseline pupil diameter across tasks and groups, suggesting participants were equally aroused/engaged in the experiment. Our results highlight the role of musical expertise in crossmodal attention.

33.438 **Attentional Effort and Efficiency in Expert Dancers** Anna Riley-Shepard[1](arileyshepard@gmail.com), George A Alvarez[1]; [1]Harvard University

Humans fluctuate naturally between two attentional states – characterized in some literature as good "on-task attention" and bad "mind wandering." However, these states can also be characterized in terms of attentional effort available (high vs. low). Here, we ask whether dancers have gained perceptual expertise that enables them to perform complex tasks even with divided attention or while in a "mind-wandering" state. In dance expertise, the effectively infinite movement possibilities dancers face when mimicking/learning dance sequences ensure that changes in required attentional effort are not attributable to proceduralization alone. Experiment 1 tested whether dance expertise transforms dance movement mimicry into a low-effort attention task. In a dual-task paradigm, we asked expert dancers (n=7) to watch and mimic 10s dance videos 1) with no secondary task, 2) while counting randomly presented auditory beeps, or 3) while performing mental math with the beeps. Subjects were recorded with an Xbox One Kinect sensor, and three expert dancers rated the movements' accuracy and timing. The dancers' performance was unaffected by either of the secondary attention tasks. Experiment 2 investigated whether, under naturally fluctuating attention, low-effort attention supports real-time reacting, but not remembering (due to added processing demands that require high-effort attention). Dancers (n=20) watched and mimicked dance videos, which stopped randomly every 40-80s. They indicated their attention state and tried to replicate their last few mimicked movements. Sensor recordings of the mimicked and replicated movements were analyzed using a Kinect machine learning gesture recognition software trained on the recordings from Experiment 1. As hypothesized, memory for the movements suffered significantly during low-effort attention ($t=2.35$, $p=0.02$), while real-time mimicry remained unimpaired ($t=-0.45$, $p=0.67$). These studies suggest that it may be adaptive (even optimal) to perform low-effort tasks in a mind-wandering state, and b) introduce a new method of studying complex actions with the Kinect.

3D Perception: Depth and cue combination

Sunday, May 20, 8:30 am - 12:30 pm

Poster Session, Pavilion

33.439 **Texture compression and scaling both contribute to perception of 3D slant from texture** Jeffrey A Saunders[1](jsaun@hku.hk), Zhongting Chen[1,2]; [1]Department of Psychology, University of Hong Kong, [2]Key Laboratory of Brain Functional Genomics (STCSM & MOE), School of Psychology and Cognitive Science, East China Normal University

The projected image of a textured surface contains multiple texture cues to its 3D surface orientation, including the change in the scaling of texture across the image and anisotropic compression of texture due to foreshortening. There remains debate about the role of these cues in 3D slant perception. Some cue perturbation studies have observed a strong influence of texture compression and weaker influence of scaling (e.g., Rosenholtz & Malik, 1997; Knill, 1998), while Todd, Christensen & Guckes (2010) found that slant estimates were predicted by texture scaling but not compression. We investigated the relative influence of texture scaling and compression cues for 3D slant perception using a slant estimation task and stimuli with small cue conflicts. Cue conflict stimuli simulated views of planar surfaces slanted around a horizontal axis by 0°–60°, and covered with texture that was compressed or stretched along the tilt direction by ±10% or ±20%, which alters texture compression but not scaling. Consistent cue stimuli were also presented with slants varying from 0°–70°. We compared slant estimates in cue conflict conditions to those in consistent cue conditions with matching texture compression or scaling cues to assess their relative influence. Experiments 1 and 2 presented monocular images with 10° or 20° field-of-view, with textures composed of either circles or irregular voronoi cells. In all cases, slant estimates were mainly determined by compression information. For the voronoi textures, there were small effects of field-of-view, suggesting an influence of texture scaling, while for the circle textures these effects were not detectable. Experiment 3 presented binocular views of the same simulated conditions and observed an influence of texture compression even with conflicting stereo information. Our results demonstrate that texture compression can substantially influence to perception of slant from texture, consistent with earlier findings that multiple texture cues are utilized by the visual system.

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33.440 **Perceptual integration of perspective and stereoscopic cues in macaque monkeys** Ting-Yu Chang[1,2](tchang47@wisc.edu), Byounghoon Kim[1], Adhira Sunkara[3], Ari Rosenberg[1]; [1]Department of Neuroscience, School of Medicine and Public Health, University of Wisconsin-Madison, Madison, WI, USA, [2]Physiology Graduate Training Program, University of Wisconsin-Madison, Madison, WI, USA., [3]Department of Surgery, School of Medicine and Public Health, University of Wisconsin-Madison, Madison, WI, USA.

Successful interactions with the world often require robust (i.e., accurate and precise) three-dimensional (3D) visual perception. Robust 3D perception can be achieved through the weighted integration of distinct sensory signals, such as perspective and stereoscopic cues, based on their reliabilities. Because the reliabilities of these cues are differentially affected by viewing conditions (e.g., object distance and slant), dynamic cue-reweighting is critical for robust perception. Here we test if robust 3D perception is achieved through dynamic cue reweighting in non-human primates. Two rhesus monkeys were trained to report the tilt (0° to 315° in 45° steps) of a planar surface in an 8 alternative forced choice task. The planes were rendered virtually and defined by perspective cues only, stereoscopic cues only, or both cues. To manipulate cue reliability, the distances (37 to 137cm) and slants (15° to 60°) of the planes were varied. All stimulus combinations were interleaved and presented pseudo-randomly. To quantify tilt perception for each cue type, distance, and slant combination, the probability of reporting each tilt was computed, and the data fit with a von Mises density function over tilt. The accuracy and precision of tilt perception were defined by the mean and concentration parameters of the fit, respectively. Tilt perception was unbiased, and therefore accurate in all conditions. The precision of tilt perception based on perspective cues was independent of distance and increased with slant. The precision of tilt perception based on stereoscopic cues showed a distance x slant interaction, falling off more slowly with distance at larger slants. A comparison of combined-cue tilt perception measured empirically and predicted using cue integration theory further revealed that the cues were optimally integrated to maximize the precision of tilt perception. These results demonstrate dynamic, reliability-dependent reweighting of perspective and stereoscopic cues by non-human primates to achieve robust 3D visual perception.

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33.441 **Shape constancy in anaglyphs: Effects of drawing training** Kelly Edwards[1](kne@uoregon.edu), Alexander J. Bies[1], Atsushi Kikumoto[1], Stefanos Lazarides[1], Margaret E. Sereno[1]; [1]Psychology Department, Art and Sciences, University of Oregon

People vary widely in their innate ability to draw figures realistically. Drawing training should improve the ability to ignore 3-dimensional context to draw apparent shape instead of the figure's physical characteristics (overcoming shape constancy effects). Here, we used skeletal outlines of cuboid polyhedrons and quadrilateral surfaces, rotated around the viewing plane and lacking texture and shading, which were rendered as anaglyphs to elicit the perception of 3-dimensional objects. Fifty-three participants completed a shape constancy task, in which they were instructed to report the physical or apparent width of a shape using the method of adjustment over a series of 768 trials. Trials were completed in blocks of 48 trials, consisting of 2 repetitions of 8 angles of rotation of 3 object widths, all of a particular level of instruction (physical or apparent width) and context (absent or present). Participants also completed a survey about their training in realistic drawing, which was used to form two groups – those who had taken a college-level course in realistic drawing (24 "artists") and those who had not (29 "non-artists"). Statistical analyses on the magnitude of width judgment errors, averaging across repetitions and object width, revealed significant three-way interactions among instruction, context, and angle (replicating our previous results) and instruction, context, and training in art. Participants from both groups (artists and non-artists) performed equally when making judgments about quadrilateral surfaces' physical and apparent widths. As might be expected, artists made smaller errors when judging the apparent width of cuboid polyhedrons. However, these artists made larger errors when judging the physical width of cuboid polyhedrons. This is the first evidence that there is possibly a cost to training in realistic drawing. Further studies are required to determine whether drawing training shifts perception toward the apparent image, and whether innate drawing skill produces similar effects.

33.442 **Microparallax is preferred over blur as a cue to depth order at occlusion boundaries** Dmitrii Tiron[1](dmitriitiron@gmail.com), Michael Langer[1]; [1]McGill University, School of Computer Science

When an observer moves laterally in a scene, edges of foreground objects occlude or reveal parts of the background. These accretion-deletion effects have been studied for large motions and are believed to provide a strong ordinal depth cue. Here we examine accretion-deletion effects that result from very small head movements such as occur during small postural adjustments. We call such motion "microparallax". An example of the magnitude we consider is that the eye moves laterally over a distance of a few mm, and is viewing a foreground and background surface at distance one and two meters, respectively. The stimuli in our experiment consisted of a densely textured foreground and background in a bipartite field. The textures consist of lines and curve fragments of random orientations and position. A range of relative retinal image speeds was used, with means from 0.1 to 0.5 deg/sec, and motion duration of about 600 ms. We found that accretion-deletion effects are a strong cue to ordinal depth in these conditions. The stimuli also contained rendered defocus blur, namely either the foreground or background object was blurred by a variable amount and the edge blur provided a potential ordinal depth cue [Mather, 1996]. The accretion-deletion cue was generally preferred over the blur cue. Our findings suggest that accretion-deletion is an important cue to depth even in situations of tiny postural adjustments of a few mm where one normally does not consider the observer to be moving.

33.443 **An object's material properties provide motion cues to three-dimensional shape** Masakazu Ohara[1](ohara16@eiiris.tut.ac.jp), Juno Kim[2], Kowa Koida[1,3]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, Japan, [2]School of Optometry and Vision Science, University of New South Wales, Australia, [3]Electronics-Inspired Interdisciplinary Research Institute, Toyohashi University of Technology, Japan

How do we effortlessly untangle complex mashes of image structure to visually infer the shape and surface quality of 3D objects? We explored whether different surface optics improve global shape perception. We created virtual objects varying in surface optics (matte, specular, refractive (with/without specular reflection)), relief (smooth, bumpy), and stretch in shape along the viewing axis. Rendering were performed in the natural environments (Eucalyptus Grove, and St. Peter's Basilica, Debevec 1998). The objects oscillated in 1 Hz horizontally and displayed for 5 s on a flat screen. Eight observers used an analog scale to match the shape of the 3D object's appearance as elongated (like a rugby ball) or flat (like a pancake). No response feedback was given. We found that the flat objects with specular reflection were perceived elongated compared with matte surfaces (similar to Mooney and Anderson, 2014). Any surfaces containing specular components with or without refractive components showed similar results. We also found that the refractive objects without specular reflection were perceived flatter than the other objects for all elongated shapes. These effects were consistently observed for objects of different sizes, binocular and monocular viewing, and even for static images. Refractive index (RI) distorts the image structure necessary for 3D shape perception, so we expected perceived shape to vary with RI. However, we observed that 3D shape perception was significantly 'flatter' for refractive materials, compared with purely diffuse and specular materials. The observer underestimates of convexity in refractive objects can be explained by velocity of the optic flow field.

33.444 **Tight shadows shrink depth** Patrick Cavanagh[1,2,3](patrick.cavanagh@parisdescartes.fr), Roberto Casati[4], James H Elder[3]; [1]Department of Psychology, Glendon College, Toronto, ON, Canada, [2]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA, [3]Centre for Vision Research, York University, Toronto, ON, Canada, [4]Institut Jean Nicod, CNRS-EHESS-ENS, Paris, France

Sunday AM

When an object casts a shadow on the surface behind it, we get a strong impression of depth separating the object and the rear surface. Kersten and Mamassian (1996) demonstrated this with a cast shadow that moved in and out below a static square, making the square appear to approach and recede in depth. There was no visible light source and the shadow motion could have been caused by a moving light source. Instead, viewers assumed a fixed light and a moving object where the depth of the object scaled with the offset of its shadow. Here we report a particularly strong light source bias in the case of "tight shadows", shadows that have very small offsets from the object casting them, as is often seen with flash photography. The small offset between object and shadow is due to the light source being near the point of view of the observer or camera. However, rather than attributing the tight shadow to the light source location, observers instead attribute it to a very small separation between the object and the rear surface. This bias – "tight shadow equals small separation" – leads to paradoxical impressions of objects impossibly close to their backgrounds. However, it is consistent with the expected object to background separation averaged over all possible light source directions, e.g., lights to the left for right shadows. In this framework, tight shadows are most likely to be caused by shallow relief.

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33.445 **The influence of a shadow cognitively casted on surfaces on the depth perception in the stereopsis** Ouri Fujiya[1](r201770033rg@jindai.jp), Tatsuya Yoshizawa[2], Tsutomu Kusano[2], Shinya Saida[2]; [1]Graduate School of Human Sciences, Kanagawa University, [2]Department of Human Sciences, Kanagawa University

It has been known that monocular and binocular cues as a primal visual information mainly produce depth perception. Our question is whether this perception mechanism can be affected by cognitive cue, such as a shadow of an object on a surface making locate at discrepant depth defined by binocular cue of that object. To investigate this question, we measured a subjective depth between a reference rectangle, which has a certain depth defined by a binocular disparity, and a test rectangle which is or is not as a candidate of a shadow of the reference rectangle. In the case of a candidate of the shadow, some part of the test rectangle spatially overlapped (occluded) over the reference rectangle, and the test rectangle did not overlap over the reference rectangle in the case of a non-candidate. The subjective depth for the both cases was measured for five undergraduates as a function of a binocular disparity difference between the test and reference rectangles. We found that in the candidate case, the reference rectangle was always perceived in front of the test rectangle against any depth difference caused by the binocular disparity cues, whereas the perceived depth of the reference rectangle to the test rectangle was followed by the depth information defined by the binocular disparity in the non-candidate case. That is, a cognitive cue such that the test rectangle was cognitively casted on the reference rectangle as a shadow determined the perceived depth prior to low level cues such as the binocular disparity and the occlusion. These suggested that if there is discrepancy of the depth information between low level cues and cognitive cue, the latter is dominantly employed as the depth information.

33.446 **Reflections on Depth from Reflections: Discounting Surfaces** Michael A Crognale[1](mcrognale@unr.edu); [1]Dept. of Psychology, University of Nevada, Reno

Many surfaces produce both specular and diffuse reflections from point-sources of light. It has been proposed that these specular components provide information about both the source (e.g. for achieving color constancy) and the surface (e.g. both texture and shape). However, specular reflections might also be treated by the visual system as objects (or images) of interest themselves. It is well known that images of extended objects reflected from curved surfaces such as mirrors can be perceived at various depths depending upon the curvature of the surface. The appearance of depth is greatly enhanced by the addition of disparity arising out of the optical geometry. However, most specular reflections produce only weak stereoscopic depth effects since the reflections appear to be correctly attributed to a distant source of light reflected from the surface. In other words, disparity in this case is discounted with regard to depth but may be used to infer surface curvature. But, what happens to the disparity information if the information about the surface is reduced or removed? Here we report observations of depth from stereopsis of specular reflection from curved surfaces that have been placed into rotational motion so as to obscure the surface cues. This effect is easily demonstrated with a chrome-plated version of a currently popular toy, called a "finger spinner" or a "fidget-spinner". If the device is spun rapidly in the presence of a point-light source then the surface features of the spinner are obscured yet the specular reflections remain. The result is that the reflections from convex and concave surface features produce patterns that are seen in striking depth that far exceeds the dimensions of the toy itself. Further investigations show generalization to any curved surface as predicted by the geometry and that the effect depends upon surface information.

33.447 **Face superiority - Cartoon 3-D faces produce a stronger depth-inversion illusion than geometric objects that share the same basic bounding contour.** Attila Farkas[1](ajf215@ruccs.rutgers.edu), Thomas V Papathomas[1,2], Steven M Silverstein[3], Tome Grace[4]; [1]Laboratory of Vision Research, Center for Cognitive Science, Rutgers University, [2]Department of Biomedical Engineering, Laboratory of Vision Research, Center for Cognitive Science, Rutgers University, [3]Division of Schizophrenia Research, Behavioral HealthCare and Robert Wood Johnson Medical School, Department of Psychiatry, Rutgers Biomedical and Health Sciences, [4]Psychology Department, Rutgers University

Introduction: Perhaps the best known depth inversion illusion (DII) is the hollow-face illusion, in which a concave face mask is misperceived as convex; when it rotates, it is perceived rotating in the opposite direction. DII is possible with other concave objects, even with a hollow ovoid surface, but the illusion strength is much weaker. Two possible causes for the hollow-face illusion are a general convexity bias and face-specific stored knowledge that influences the visual input. The current project aimed to look for these effects in the presence of abstract facial and non-facial features. Method: We generated six computer-rendered 3D wire-frame objects that shared the same bounding contour; the bounding contour was a planar closed oblong wire-frame shape that resembled the outline of a frontal view of a face. Each object had a concave and a convex side. The two face-like objects were: (1) FN, with eyebrows and nose contour; (2) FNM, same as FN, with added mouth. The non-face objects were: (3) nFX, with two crossing diagonal contours; (4) nFV, with two nearly vertical non-crossing contours; (5) fNH, with nose, eyebrows and mouth rotated 90º clockwise. The last stimulus, (6) F+nF was the union of FNM and nFX stimuli. To provide kinetic depth information, each object was rotated clockwise or counterclockwise at 10 degrees/second. Results: DII was present for both concave and convex objects, but significantly stronger for concave objects (convexity bias). DII was equally strong for FN and FNM. DII was significantly stronger for face than for non-face stimuli. Performance with F+nF was closer to non-face than to face stimuli. Conclusions: Results suggest that DII is stronger for concave objects for both face and non-face stimuli, providing support for a general convexity bias. The increased frequency of DII occurrence for face-like objects indicates the presence of face-specific influences.

33.448 **The role of binocular disparity in depth-inversion illusions studied with synopters and pseudoscopes** Thomas V Papathomas[1,2](papathom@rci.rutgers.edu), Nicola Bruno[3], Attila Farkas[1]; [1]Laboratory of Vision Research, Center for Cognitive Science, Rutgers University, [2]Department of Biomedical Engineering, Rutgers University, [3]Department of Medicine and Surgery, University of Parma

Introduction: Depth-inversion illusions (DII) offer examples in which stored knowledge overcomes visual cues and causes 3D objects to be perceived in opposite depth: points located physically closer appear to be behind points located physically further, thus transforming convexities into perceived concavities and vice versa. Viewers moving in front of DII stimuli perceive them to move (illusory DII motion). We manipulated the binocular disparity (BD) cue to study its role in DII. Methods: We used large (height > 80 cm) realistically painted hollow masks (HM) and reverse-perspectives (RP) as DII stimuli (DIIS); painted cues and the 3D geometry were incongruent. We also used their depth-opposites: a normal 3D mask (NM) and a proper-perspective (PP) that are normally not depth-inverted stimuli (nDIIS). Subjects viewed DIIS (HF and RP) and nDIIS (NM and PP) from 3 meters, monocularly and binocularly, as

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well as using a synopter (identical eyes' views, BD=0) and a pseudoscope (left and right eye views swapped; BD is the negative of its value under normal viewing). Results: DII was strongest under pseudoscopic viewing and weakest under binocular viewing, with synoptic and monocular viewing yielding intermediate strengths as expected, for both DIIS. DI was impossible for nDIIS under all conditions. It was nearly impossible when viewers saw only the top or only the bottom parts of nDIIS for all conditions, but it became possible under pseudoscopic viewing. Illusory motion was always present when DII was present. Conclusions: BD opposes DII under binocular viewing, because it signals veridical depth. As expected, DII strength increases under monocular or synoptic viewing (BD=0), reaching its maximum under pseudoscopic viewing, because BD signals illusory depth under pseudoscopy. The above confirms BD as a strong cue for recovering 3D shape. However, BD's weak effect on nDIIS indicates its limits as a cue for 3D shape recovery.

33.449 **The combination of 3D motion cues in Virtual Reality** Mohan Ji[1](mji24@wisc.edu), Jacqueline M Fulvio[1], Bas Rokers[1]; [1]Department of Psychology, University of Wisconsin - Madison

In the natural environment, many visual cues signal object motion. In the laboratory, the contribution of these cues to perception is often studied in isolation. Here we exploit virtual reality (VR) technology to study the rich interaction between perspective, disparity, and parallax cues to object motion in a large sample of participants. Naïve observers (N = 91) viewed 3D random dot motion stimuli in a VR head-mounted display (Oculus Rift). We measured psychophysical thresholds for the discrimination of approaching and receding motion by varying motion coherence of dot stimuli that contained perspective, disparity, combined (perspective and disparity), or full VR (combined + motion parallax) cues to 3D motion. Ten observers did not have a detectable threshold in any of the conditions and were removed from further analysis. Observers were sensitive to both the perspective and disparity cues to 3D motion. However, sensitivity to perspective cues generally exceeded disparity sensitivity. Critically, we did not find a significant correlation between perspective and disparity sensitivity. A model assuming the two independent cues are combined optimally predicted combined cue performance well, $F(1,72) = 7.60$, $p < .01$. Finally, we did not find evidence for greater sensitivity to the Full VR condition in our experiments. In summary, our results indicate the mechanisms for processing the perspective and disparity cues are independent. Furthermore, sensitivity to both cues combined can be characterized based on sensitivity to either cue in isolation. Finally, we did not find evidence for superior sensitivity when motion parallax cues were available, suggesting that the naïve participants in our experiments could not take advantage of the head-contingent updating feature of VR displays. Our results inform neural models of 3D motion processing under naturalistic conditions.

Acknowledgement: Google Research Grant

33.450 **Perception of Object Movement in Virtual Reality** Rowan T Hughes[1](rowanthughes@gmail.com), Peter Scarfe[2], Paul B Hibbard[1], Loes C J van Dam[1]; [1]University of Essex, [2]University of Reading

Virtual Reality (VR) represents a paradigm shift in terms of user experience and immersion within a virtual environment. Van Dam, Li & Ernst (2012;2016) investigated how proprioceptive and visual information are integrated over time, leading to a perceived lag and increased precision, in a distal display. We extend this approach to investigate how visual information is integrated over time in VR and whether the increased latent information, such as parallax and binocular depth cues., plays a role in participant performance. Two separate experiments were run. In both experiments participants were placed in a VR space, using an Oculus headset, where a target moved horizontally for variable durations of time at approximately 1m from eye level. The target could either be reliable (single dot) or unreliable (Gaussian dot cloud) in terms of its position. Participants were asked to judge whether the last target position was to the left or right of a comparison stimulus shown after target disappearance. In the first experiment the target stimulus remained consistent in its display (Continuous Movement condition). In the second experiment the target stimulus was displayed intermittently (Intermittent Movement condition, see Van Dam, Li, Ernst, 2016), for a duration of 200ms every 500ms, thus decreasing the reliability of the target velocity. Results show that for target judgements in the Intermittent Movement condition, participants integrated position information over time, leading to a perceived lag of the unreliable target in space. This confirms previous results by Van Dam et al. (2016). For the Continuous Movement condition there was no difference in lag between unreliable and reliable targets, indicating that participants use the velocity signal to predict target position. For the unreliable target in this case we found a significant improvement in perceptual precision, indicating that information is integrated over time.

33.451 **Driving accommodation using simulated higher-order aberrations** Steven A Cholewiak[1](steven.cholewiak@berkeley.edu), Gordon D Love[2], Martin S Banks[1]; [1]Optometry & Vision Science, UC Berkeley, Berkeley, California, USA, [2]Departments of Physics & Computer Science, Durham University, Durham, UK

The purpose of accommodation is to minimize blur. Defocus blur is the major source of blurring in the retinal image, but defocus blur itself cannot tell the eye if it is focused too near or too far. When the human eye is shown real blur, accommodation always changes in the correct direction without searching, so the visual system can somehow determine the sign of defocus. Potential signals for the sign include temporal fluctuations of accommodation (e.g., microfluctuations), chromatic aberration, and higher-order aberrations (HOAs). We investigated whether simulated HOAs—specifically, astigmatism and spherical aberration—provide the needed sign information to drive accommodation in the right direction. Measurable astigmatism occurs in most people; its magnitude and axis varies across individuals. The point-spread function (PSF) of a defocused astigmatic eye is elliptical with the major axis in one direction when the object is farther than current focus and that axis rotated by 90deg when the object is nearer. Spherical aberration is also present in nearly all people. It generally causes marginal rays through the pupil to focus in front of the retina when central rays are focused on the retina. Because of this marginal-central difference, spherical aberration creates different PSFs for objects at different depths relative to the eye's current focus. Therefore, astigmatism and spherical aberration can in principle provide sign information to guide accommodation in the correct direction. We investigated whether they really do aid accommodation. We measured observers' aberrations with a Shack-Hartmann wavefront sensor and generated rendered stimuli that simulated either their native astigmatism or spherical aberration for various simulated distances. We found that simulated astigmatism and spherical aberration can indeed drive accommodation in the right direction, but they are less effective than real changes in focal distance. We conclude that these natural aberrations provide useful sign information for accommodation.

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3D Perception: Space

Sunday, May 20, 8:30 am - 12:30 pm

Poster Session, Pavilion

33.452 **Explicit estimates of angular direction are more expanded in elevation than in azimuth, even with sideways observers** Umi I Keezing[1](ukeezin1@swarthmore.edu), Frank H Durgin[1]; [1]Department of Psychology, Swarthmore College

The angular expansion hypothesis has observed that ground distances are misperceived in a manner consistent with an exaggerated scaling of angular declination (elevation) with a gain of 1.5 and a smaller, but still exaggerated (~1.25) scaling of perceived azimuth direction relative to straight ahead. In the present study we sought to measure whether the explicit estimation of angular direction occurs with respect to the reference frame defined by a visible ground plane (even for sideways observers) or the reference frame defined by the body (e.g., for a sideways observer). In a series of three experiments we tested observers in a stereoscopic virtual environment (back-projection screen) with a FOV extending 70° to the right from straight ahead in azimuth (each direction probe was presented along this physical axis). Upright or sideways-lying participants made angular direction judgments (in degrees) with respect to a ball suspended in space at a distance of 8 m along the same (gravitational azimuth) axis. Directions ranged from 3 to 51°, presented in random order. The straight-ahead was represented by a distant pole in the upright-world conditions, and by the rotated horizon in the sideways-world conditions. Both upright

Sunday AM

observers and sideways observers showed a gain of 1.3 in visual-world azimuth with a (gravitationally) upright world. When the world was gravitationally sideways (so that judgments were of angular elevation above a depicted ground plane), sideways observers showed a gain of about 1.5, consistent with the expected scaling for elevation. This gain was reliably higher than their 1.3 gain for azimuth in the gravitationally-upright world. These results for explicit estimation of angular direction are consistent with prior studies of perceived distances and heights for sideways observers that also suggest the dominance of the visual reference frame (Li & Durgin, 2016, JOV 16(1):4; Klein, Li & Durgin, 2016, JEP:HPP, 42, 581-593) .

Acknowledgement: NEI R15 EY021026

33.453 **Distinguish egocentric distance perception from traveled distance perception.** Thomas Rousset[1](thomas.rousset@etu.univ-amu.fr), Christophre Bourdin[1], Jean-Louis Vercher[1]; [1]Aix-Marseille Université, CNRS, ISM UMR 7287, Marseille, France

Virtual reality tends to generalize for the study of human behavior in mobility. It is thus crucial to ensure that perception of space and motion is little or not affected by the virtual experience. Regarding visual perception of distances it is common to differentiate between two types of errors: errors in the estimation of egocentric distance and errors in the estimation of traveled distance. Nevertheless, the majority of studies carried out in this field do not distinguish these two errors. Thus, starting from the hypothesis that these two types of errors coexist in virtual reality, we propose in this study a first approach to remove the current ambiguity between egocentric distance and traveled distance through a continuous pointing task. The distance to be estimated and the speed of movement were varied. By comparing the data collected on eighteen participants to a computational model with two parameters: an initial error parameter (egocentric distance) and a parameter accumulating the error during the movement (distance traveled), we evaluated the weight of each of these two errors in the observed behavior. The results show that it is possible to set up an experimental protocol allowing discrimination between the two types of error. These results also reveal that errors resulting from the perception of egocentric distance are much greater than that resulting from the perception of distance traveled. Finally, this study highlights the importance of considering the issue of spatial visual perception in a less fragmented way and gives a first clue to the fact that the error generally observed in the estimation of the traveled distance would be mainly due to an error in estimating the egocentric distance.

33.454 **Detecting 3D location change in the presence of grouping cues** Ellis L Gootjes-Dreesbach[1](E.L.Gootjes-Dreesbach@reading.ac.uk), Peter Scarfe[1], Andrew Glennerster[1]; [1]School of Psychology & Clinical Language Sciences, University of Reading

Blindness to image change is well documented, but detection of 3D location change (as opposed to 3D motion) is less well characterised. Very large changes in the size of a scene can go unnoticed (Glennerster et al, 2006) but this is not something that a computer vision system could detect from the input images alone. Here, we measured the detectability of changes in the 3D location of an object relative to other, static objects when observers did not know which object was going to move. 8 spheres were presented in virtual reality (arranged in two groups at distances between 2.5-7.5m); the task was to detect which one moved (by 2m, towards or away from the observer). We have shown (VSS 2017) that joining pairs of spheres with lines ('dipoles') dramatically reduces the ability of participants to detect the moving object if (and only if) the dipoles switch between intervals to join different pairs of spheres. This could reflect a general image change or else be due to a change in grouping of the spheres. We tested this using colour to define groups rather than dipoles. Half the spheres had one colour, half another. The colours were either reversed between intervals (no grouping change) or the colour-defined groupings changed. All colour changes were irrelevant to the 3D location change task. We find (both at individual and group level) that these colour changes, of either type, have no significant effect on performance. This is true despite 95% a priori power to detect an effect of the same size as in the original experiment. Our results in the 3D domain are closely related to findings using 2D images (Jiang et al., 2004, showed that rotation of elongated axes drawn through objects, but not colour changes, disrupted performance).

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33.455 **Searching for Invariance: Geographical and Optical Slant** Olivia C Cherry[1](ocadkins@iu.edu), Geoffrey P Bingham[1]; [1]Psychological and Brain Sciences, College of Arts and Sciences, Indiana University

When we move through rigid environments, surface orientations of static objects do not appear to change. Most studies have investigated the perception of optical slant which is defined in an egocentric frame of reference and thus, is entirely dependent on the perspective of the observer. We investigated the perception of geographical slant, which is invariant across different viewing perspectives, and compared it to optical slant. In Experiment 1, participants viewed a 3D triangular target surface covered with triangular phosphorescent texture elements presented at eye level at one of 5 slants from 0° to 90°, each at 0° or 40° tilt. Participants turned 180° to adjust a 2D line or a 3D surface to match the slant of the target surface. In Experiment 2, the difference between optical and geographical slant was increased by changing the height of the surface to be judged. In Experiment 3, target surfaces were continuously rotated +/- 25° and viewed in the dark as well as in a lighted room. In Experiment 1, the overall pattern of judgments exhibited only slight differences between response measures. In Experiment 2, slant judgments were slightly overestimated when the surface was at a low height and at 0° tilt. We compared optical slants of the surfaces to geographical slants. While sometimes inaccurate, participants' slant judgments remained invariant across changes in viewing perspective. Optical slants failed to predict mean judgments. In Experiment 3, judgments were the same in the dark and lighted conditions. There was also no effect of motion on mean slant judgments, although motion decreased variability. We conclude that participants' judgments were invariant as predicted by geographical slant although with an overall mean error of about 5°. Judgments did not vary as predicted by optical slant.

33.456 **Pathing judgment on planes and spheres: Accurate intuitions about shortest paths** Matthew Jordan[1,2](matthew-jordan@live.ca), Yuval Hart[3], Moira R Dillon[2]; [1]Department of Experimental Psychology, University of Oxford, [2]Department of Psychology, New York University, [3]Paulson School of Engineering and Applied Sciences, Harvard University

Humans alone are capable of formal geometry, like the one outlined in Euclid's Elements. We can conceive of points of no size and lines of infinite length. How do we conceive of such points and lines without ever perceiving them? We examined adults' (N=48) capacity to judge the shortest path between two points (i.e., linearity) on pictures of planes and spheres (Fig. 1). Our primary analysis focused on whether participants' success depended on three factors: surface (plane vs. sphere); planar linearity (i.e., a line vs. curve); and spherical linearity (i.e., a geodesic vs. arc). While participants were more successful at judging the shortest paths on planes vs. spheres ($P < .001$; Fig. 2), they were nevertheless above chance (.50) when judging geodesics that were also either lines ($P < .001$) or curves ($P < .001$). Indeed, participants modulated their responses based on the surface (Surface X Planar Linearity, $P < .001$; Surface X Spherical Linearity, $P < .001$). Nevertheless, participants were more accurate at judging geodesics that were also lines vs. geodesics that were also curves ($P < .001$, holm-corrected). Finally, spherical judgments were more accurate with smaller spheres, longer paths, and paths closer to the poles (all $Ps < .001$). Participants' success with geodesics is surprising because prior work has shown a planar bias in adults' commonsense geometric reasoning (e.g., Izard et al., 2011) and because formal spherical geometry is rarely taught in school. Future work may examine how human and animal navigation may underlie such accurate path judgments (e.g., Jeffery et al., 2013; Urdapilleta et al., 2015), and how such judgments may depend on development of visual form processing (e.g., Ons & Wagemans, 2011). Ultimately, this work aims to bridge our perception of spatial entities to our conception of geometric formalisms.

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33.457 **Gravity and ground plane geometry in perspective images.** Elodie Fourquet[1](efourquet@colgate.edu), Flip Phillips[2]; [1]Department of Computer Science, Colgate University, [2]Department of Psychology and Neuroscience, Skidmore College

Renaissance artists noticed that placing objects on a visible ground plane anchors them stably, making it easy to perceive their depth. Subsequently, they developed methods for geometric calculation of perspective by drawing construction lines defining the ground plane. Thus, the artist constructs the geometry of pictorial space, based on the station point and the view direction, then places objects in it. This practice created a scale for placing and sizing objects on a minimally patterned ground plane. Our experiments, which measure the precision of depth perception in perspective images, hypothesize that spatial perception evolved in the presence of two constancies, vertical gravity and an almost horizontal ground. Human sensitivity to horizontal and vertical orientations exemplifies the important effect that gravity and the ground have on human perception. From them a third constancy emerges, objects in contact with the ground at the same distance lie along a horizontal line, which artists' floor constructions highlight. In psychophysical experiments we measured the response time and accuracy of forced-choice closer/farther judgments between two objects placed in simple scenes based on traditional artist's perspective. The presence or absence of ground constructions and its orientation are varied in SVG images to minimize pixellation artifacts. Among the directions of gravity participants best perceive depth when the ground plane is horizontal and gravity downward, as measured by response time at 97% accuracy. Furthermore, the horizontal construction lines, which abstract the horizontal guides present in Renaissance paintings the tiled floors, improve depth perception substantially. In Renaissance scene paintings feet are usually visible; our experiments show that the feet provide the viewer with an accurate perception of relative depth, configuring the scene elements into clusters. The underlying cause lies in the structure of vision, which privileges the horizontal ground and downward gravity.

33.458 **Distance perception in the VR was determined by where you virtually are and where you really are** Junjun Zhang[1](jjzhang@uestc.edu.cn), Xiaoyan Yang[1]; [1]School of Life Sciences and Technology, University of Electronic Science and Technology of China

The peculiar experience of virtual reality (VR) is that you are in one real location while your vision is browsing another virtual scene. It is still unknown whether the virtual scene alone, or both the virtual scene and the real location determine the perception in the VR. In this study we investigated the distance perception in different virtual scenes and real locations. Two virtual scenes replicated a real indoor hall and a real outdoor pathway, respectively. Those two scenes were displayed by the HTC vive VR headset in this study. The virtual scenes did not replicate all the details of the real locations, but the sizes of the spatial layouts were identical. The first experiment was carried out in our lab room, where observers were asked to perform a bisection task and an L-shape matching task in the two virtual scenes. Results showed that the performances of both the tasks were different in the two scenes. It demonstrated that the distance perception was affected by the layout of the virtual scene. The second experiment was carried out in the real hall and on the real pathway, one after another. At each location, observers performed a blind-walking task to a pre-showed target presented in two virtual scenes. Results showed that not only the virtual scene, but also the real location affected the egocentric distance perception. That is, when the observers were outdoor on the pathway, the judged distance was further away than the judgment made in the hall, even though the task was irrelevant to the real locations. To summarize, the distance perception in the VR was determined by both the real location that you are in and the virtual scene that you are browsing.

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33.459 **Depth constancy for virtual and physical objects** Brittney A Hartle[1](brit1317@yorku.ca), Matthew D Cutone[1], Laurie M Wilcox[1]; [1]Department of Psychology, and Centre for Vision Research, York University

It is generally assumed that stereopsis plays an important role in 3D shape perception; if so, the disparity-defined shape signal must be consistent across a range of viewing distances. Studies of stereoscopic depth constancy have used a wide variety of stimuli and tasks, and come to similarly wide-ranging conclusions. The aim of this series of experiments is to understand how perceived depth magnitude is impacted by viewing distance, cue conflicts, and surface structure in virtual and physical objects. To this end, we measured perceived depth magnitude using virtual textured half-cylinders and identical 3D printed versions, presented at 83 and 130cm. Virtual stimuli were viewed using a mirror stereoscope and an Oculus Rift head-mounted display. The physical stimuli were viewed in a controlled environment under similar lighting conditions. In all cases, observers used a pressure-sensitive strip to indicate the maximum depth of the cylinder, with stereopsis and without (monocular). Depth estimates were similar in the two virtual viewing conditions, despite the optical distortions and lower resolution of the VR display. Performance was more accurate when viewing physical objects. In all three conditions there was incomplete scaling of depth with viewing distance, but this was less extreme in the physical test condition. To estimate the 'assumed' distance to the object, we used each observers' estimate, binocular geometry, and maximum likelihood estimation. Comparison of the ratio of the presented distances to those computed from the results, suggests that distance was underestimated by about 22% in both the VR and stereoscope conditions. We conclude that the failure of depth constancy in virtual stimuli is not modulated by the degree of vergence-accommodation conflict, and that depth constancy is not complete, even for physical stimuli.

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33.460 **The effects of environmental context upon distance bisection** Catherine J Dowell[1](catherine.dowell339@topper.wku.edu), J. Farley Norman[1], Alexia J. Higginbotham[1], Nicholas W. Fedorka[1], Hideko F. Norman[1]; [1]Psychological Sciences Department, Ogden College of Science and Engineering, Western Kentucky University

In the current study, 28 younger and older participants visually bisected distances in depth both outdoors and indoors (half of the participants were male, half were female). Distance extents of 15m and 30m were judged in four different environmental settings (an indoor hallway & atrium, as well as two grassy fields). The participants were required to place a marker at the perceived midpoint of each distance interval. In general, the participants' judgments were more accurate indoors and less accurate outdoors. In outdoor contexts, the judgments of many participants were consistent with the perceptual compression of farther distances: these participants placed the marker closer than the actual physical midpoints of the stimulus distance intervals. Age and sex significantly affected the precision and accuracy of the judgments. The male participants' judgments were more accurate than those of the female participants. In addition, their bisection judgments were less influenced by environmental setting. The accuracies of the older participants' judgments were more influenced by context than those of the younger participants. There was also a significant effect of age upon the precision of the bisection judgments -- the older female participants exhibited greater variability across repeated judgments than the older males, younger males, and younger females. These results demonstrate that sex, age, and environmental context all significantly affect visually perceived distance.

33.461 **Virtual Reality study of the influence of environment color and luminosity in depth perception** Ruggero Micheletto[1](ruggero@yokohama-cu.ac.jp), Tomoharu Nagahama[1]; [1]Yokohama City University, International College of Art and Sciences

We used a virtual reality (VR) head mounted monitor to study the relation between environmental illumination and perception of distance. We programmed the VR monitor with Unity 3D in C# language and setup a three dimensional world where two object could be seen at distance in different environmental conditions (illumination, object color etc). The subject task was to align these two objects moving one of them using a mouse. We measured the movement of the mouse, timing and precision of the final alignment of the two objects. We report differences in behavior for different illumination conditions. Different illumination in virtual reality correspond to different levels of signal in the retina. However, VR guarantees perfectly identical geometrical informations and perspective conditions. The differences in the estimation of the depth of the two objects is reflected in the subjects ability to align them. This difference is expected, but our original VR setup allow us, for the first time, to measure precisely the subjects actions and timing for quantitative analysis. Overall in this research we report for the first time quantitative analysis of the effect of illumination and color of object on their three dimensional perception by the visual system. Moreover, we measure also the positioning of the head to evaluate and study the subject effort to estimate distance. This research can be useful for the fundamental understanding of environment influence on the visual system depth perception and could have applications on civil engineering, automotive design and military sciences.

Acknowledgement: YCU Basic Research Fund

33.462 **Percept- driven versus data-driven pupil's response: effects of illusory depth.** Michael Wagner[1](Wag.michael@gmail.com), Ronen Hershman[2], Avishai Henik[2]; [1]Industrial Engineering & Psychology Ariel University, Ariel, Israel, [2]Cognitive and Brain Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel

Fixating spatial objects elicits synchronized visual processes such as accommodation, vergence and pupil response. Few studies such as Enright (1987), and Wagner et. al. (2009), indicated that vergence and pupil-response could be controlled by top-down processes. Fixating near objects in natural environments elicits pupil constriction, and far object fixation elicits pupil dilatation, these are the well-known pupil near-far responses, based on physiological physical processes. In the present study, we investigated the effects of illusory distance on the pupil dynamics. Our participants performed a detection task responding to "near" or "Far" targets, with proportional size and location to their background perspective illusory depth environment. During each trial participants performed eye-movements from central fixation towards the detected "near" or "Far" target. A fronto-parallel scrambled-image of the perspective surface served as 2-D control background for the identical targets during control trials. Eye-movements and pupil-size were measured with the EyeLink-1000 eye-tracker. Our results indicated significant differences of pupil response patterns, during detection task on the test- illusory control surfaces, as compared to the 2D control background. Our measured pupil size dynamic patterns towards illusory "near" or "Far" targets resembled the natural "near-far pupil reflex". Our data support the hypothesis of possible top-down: percept-driven control on pupil response. In an additional experiment, we could compare rapid fixational eye movements with stable target fixations. Results here support the speculation on the existence of at least two eye movement systems: an automatic, data-driven system for rapid successions of fixations, and a deliberate schema-driven system that accounts for stable fixations based on the perceptual state of the observer.

33.463 **Perceptually optimized view density for continuous parallax** Christos Kaspiris-Rousellis[1](christos.kaspiris-rousellis@newcastle.ac.uk), Adam Simmons[1], Jenny C. A. Read[1]; [1]Institute of Neuroscience, Newcastle University, Tyne and Wear, UK

Future 3-D displays are expected to effectively support full parallax visualization which would allow the viewer to experience a stereoscopic 3-D scene from multiple continuous perspectives. However, the optimal parallax density with respect to the human visual system is not yet known. In this study, we address this issue by analyzing the artifacts that arise in an image sequence replicating the changing views of a 3-D scene for a moving observer. We aimed to specify the minimal step in view density that is noticeable by measuring the visibility of the related artifacts. We simulated these effects on a passive stereo 3-D display and performed psychophysical studies to define a perceptual threshold for continuous parallax. In a 2IFC task, subjects indicated the "better looking" interval between a reference image sequence where the correct view was explicitly updated at every frame, and a distorted one where an angular sub-sampling factor was modulated to increase/decrease the severity of the artifacts. A light leakage among adjacent views was modeled in the spatial domain using a super-Lorentzian curve to account for additional display-related effects. We examined various synthetic stimuli and evaluated state-of-the-art, full-reference quality metrics in an attempt to model this behavior. We found that the top-performing metrics can be used to indirectly characterize the artifacts' visibility despite not being specifically constructed to capture distortions in the angular domain.

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33.464 **Using Visual Snapshots to Estimate Egocentric Orientation in Natural Environments** Max T Kinateder[1](max.kinateder@dartmouth.edu), Emily A Cooper[1]; [1]Department of Psychological & Brain Sciences, Dartmouth College

Accurate real-time estimates of one's orientation are essential for moving about an environment. During movement, several dynamic sensory cues contribute to estimates of heading orientation, such as vestibular signals and optic flow. We examined the ability of observers to estimate their orientation from the static information present in their local view of a scene: a "visual snapshot" taken from a specific position and orientation within a 3D environment. On the one hand, in most complex, natural environments, such local views uniquely specify the observer's position and orientation, suggesting that this task should be straight-forward. On the other hand, utilizing information from local views alone (e.g., landmarks, geometry) likely hinges on accessing an accurate 3D internal representation and discriminating between views. Using a head-mounted display, participants were immersed in an indoor environment, which recreated views of a real room at all orientations from a fixed location. On each trial, participants were shown two snapshots taken from two randomly selected orientations. Their task was to turn as if they were orienting themselves from one view to the other. We examine the effects of prior exposure to the scene and on-line visual feedback. Even with modest prior exposure, participants rapidly learned to perform the task either with or without continuous visual feedback while turning. Without visual feedback, however, their accuracy and precision were substantially lower. Our results suggest that observers can infer coarse but reasonable heading orientations from static visual information alone. We will further study how the accuracy and precision of egocentric orientation is influenced by room clutter, prior experience, and restricted visual field.

Acknowledgement: Microsoft, Oculus

33.465 **Facial orientation biases in visual vs. pictorial space** Niko Troje[1,2](troje@queensu.ca), Dean H. Rosen[1], Siavash Eftekharifar[1,2]; [1]Dept. of Psychology, Queen's University, [2]Centre for Neuroscience Studies, Queen's University

The orientation of a half-profile face presented on a screen or printed out on paper tends to get overestimated. If participants are asked to orient a face half way between frontal view and profile view, they typically choose an angle somewhere between 30 and 40 degrees. In this study, we demonstrate the phenomenon itself, and we test the hypothesis that it is directly related to presenting the face in the pictorial space of the flat screen rather than in the egocentric visual space of the observer. In our experiment, we asked participants to use keyboard presses to rotate a 3D rendering of a human head to orient it at 45 deg, that is, half way between frontal and profile view. A single block consisted of 80 trials. In each of them, the head was initially presented in a random initial orientation. Employing a repeated-measures design, participants completed two such blocks in counterbalanced order. Both viewing conditions were implemented in virtual reality (HTC Vive with Lighthouse tracking). In the first, participants saw a columnar pedestal with the head mounted on top of it in the visual space before them. In the second block, the same scene was recorded with a fixed camera and projected on a virtual computer screen. The results indicated that the mean estimates for angular orientation in visual space ($M = 43.01$, $SD = 5.96$) and pictorial space ($M = 37.40$, $SD = 6.99$) did differ significantly, $t(15) = 5.13$, $p < .001$ (two-tailed t-test). That fact that overestimation of slant angles observed in pictorial representations disappears in visual space is interpreted as evidence that the observed orientation bias is a result of depth compression due to the flatness of the picture itself which is perceived alongside with the depicted contents of the picture in a "twofold" way.

Acknowledgement: NSERC

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33.466 **Shape and Size Constancy in Consumer Virtual Reality** Rebecca L Hornsey[1](rlhornsey@outlook.com), Paul B Hibbard[1]; [1]Department of Psychology, University of Essex

The retinal size of an image, and its binocular disparity, both reduce as the distance to the object increases. In order to accurately perceive the size and shape of an object from retinal information, it is therefore necessary to know its distance. Observers typically show under-constancy, such that the apparent size and depth both tend to reduce with increasing distance. We assessed the degree of constancy for objects presented in consumer virtual reality. Observers were presented with an ellipsoid in an Oculus Rift, at distances between 40 and 100 cm at eye-height. Using the Oculus Touch controller, their task was to alter the height and width of the ellipsoid to set its size, and the depth to set its shape, to match these against a hand-held tennis-ball. Both size and depth settings increased with increasing distance, indicating under-constancy. These results show that the degree of shape and size constancy in consumer virtual reality is comparable to that found using carefully-calibrated psychophysical techniques.

Acknowledgement: ESRC, Oculus

Visual Search: Models and mechanisms

Sunday, May 20, 8:30 am - 12:30 pm

Poster Session, Pavilion

33.467 **Incidental Learning of Context-Feature Associations Impacts Attentional Set** Sunghyun Kim[1](skim58@lsu.edu), Melissa R Beck[1]; [1]Louisiana State University

Contextual cueing occurs when participants form associations between a context and the location of a search target, showing that context can guide attention for where. The present study investigated influences of context on attentional control settings for what. On each trial, two placeholders were presented separated by a fixation marker. Then a cue (four red or green dots) appeared around one of the placeholders for 50ms. After a 100ms ISI, a letter appeared in each of the placeholders (one target and one distractor) and participants indicated the identity of the target (Z or N). For the training session, the shape (circles or squares) of the placeholders and fixation marker was associated with the color of the search targets. For example, when the context was circles (squares), the color of the target was always green (red). Then in the test session, the associations were broken. If an attentional control setting is formed based on the associations, green (red) cues appearing immediately before the search target should capture attention when the context is circles (squares), leading to faster responses to targets appearing at the cued location. This expected result was observed in the test session but not in the training session, suggesting that participants learned the associations but did not use them until the test session began. This effect was replicated when the break between training and test was moved to within the training (Experiment 2) and when using color cues instead of abrupt onset color cues (Experiment 3). The present study showed incidental learning of context-feature associations and that detecting a change in the association can trigger use of the association for feature-based attentional control settings. The conflict monitoring hypothesis (Botvinick et al., 2001) may explain why the associations guided attention only after the associations were broken (in the test block).

33.468 **Large field and high resolution: detecting needle in a haystack** Hadar Gorodissky[1](gorohadar@gmail.com), Daniel Harari[1], Shimon Ullman[1]; [1]Department of Computer Science And Applied Mathematics, Weizmann Institute of Science

A general-purpose visual system needs to combine the ability to acquire highly detailed information with the ability to cover a large field-of-view (FOV). The human FOV spans over 120 degrees, with peak resolution approaching 0.5 arcminutes. Covering such a large field at this resolution will require acquiring images of roughly 200 million samples. Anatomically, such a requirement is infeasible, and computationally, current machine vision schemes will require a scaling of processing power by three orders of magnitude. Here we studied the combination of a large FOV with high-resolution in target detection tasks, given a limited 'budget' of sampling points to form an image. We compared different designs of distributing sampling points across the visual field, including non-uniform configurations. In particular, we compared models of constant resolution versus models of variable resolution inspired by human vision, with peak resolution at the center, which decreases with eccentricity. For the constant models, we compared trade-offs between resolution and FOV size. For the variable models, we compared between a single channel with varying resolution, and multiple channels, each with a different constant resolution. We focused on the challenging task of localizing small targets of interest in natural images, and compared performance using state-of-the-art deep neural nets to train models (of equal resources), which use successive steps, by fixating at the target location predicted by the preceding step. The results first indicate that the variable resolution models significantly outperform constant resolution models, and converge to the optimal, full-resolution model, using only 5% of the samples used by the full-resolution model. Surprisingly, within the variable models, the use of multiple parallel channels outperforms the use of a single, varying resolution channel. Finally, unlike constant resolution models which used a single step, variable models used multiple steps, however, model convergence was rapid, 1.5 steps on average.

Acknowledgement: This work was supported by the Israeli Science Foundation grant 320/16, the German Research Foundation (DFG Grant ZO 349/1-1), and EU's Horizon 2020 research and innovation program under grant agreement No. 720270

33.469 **Training a Convolutional Neural Network to Detect the Gist of Breast Cancer** Gaeun Kim[1](gaeunkim@ohs.stanford.edu), Arkadiusz Sitek[2], Jian Chen[3], Karla K Evans[4], Jeremy M Wolfe[5]; [1]Stanford University Online High School, [2]Philips Research, [3]Department of Computer Science and Engineering, The Ohio State University, [4]Department of Psychology, University of York, [5]Harvard University and Brigham & Women's Hospital

Previous studies show that radiologists can discriminate normal from abnormal mammograms after just 250-2000 ms of observation. Interestingly, radiologists can still discriminate normal from abnormal when the abnormal breast is the breast contralateral to the lesion. It is not clear which features/patterns of the images are responsible for successful extraction of this "gist" impression. In an effort to better understand this signal of abnormality, we have developed a convolutional neural network (CNN) model to perform the same task. This model is constructed in three steps. First, VGG-19, an established CNN, is pre-trained on non-medical images, using the imageNet database. This training makes the CNN analogous to a naïve observer, able to categorize objects but uninformed about mammography. Next, we feed full-field mammograms through the network to obtain 4096-dimensional feature vectors which are abstract representations of the original mammograms. Finally, we perform normal/abnormal classifications on mammograms using features obtained in previous step, using a supervised machine-learning algorithm. We fine-tune its parameters by performing an exhaustive grid search on the types of kernels and cost values. In a way the last step is similar to sending radiologists to medical school to teach them how to interpret the visual information represented by abstract features. The CNN produced AUC values of 0.74, comparable to our human observers. Human and computational assessments of gist are correlated (r=0.65). However, since they are not perfectly correlated, it is possible to combine human and CNN assessments of abnormality to produce a joint assessment that is better than either humans or CNN alone. The signal is not well correlated with breast density. These results show that there are global signals of abnormality that can be detected by an appropriately trained CNN. It is possible that such signals could serve as "imaging risk factors" in breast cancer screening.

33.470 **The high prevalence effect meets the low prevalence effect** Todd Horowitz[1](todd.horowitz@nih.gov); [1]Basic Biobehavioral and Psychological Sciences Branch, National Cancer Institute

A large body of research has examined the low prevalence effect (LPE) in visual search. Observers are more likely to miss targets at low prevalence (e.g., 1%-2%), compared to medium prevalence (50%). However, the effects of high prevalence (> 50%) have been comparatively neglected. In a recent meta-analysis (Horowitz, T. S. 2017. Prevalence in visual search: From the clinic to the lab and back again. Japanese Psychological Research, 59(2), 65–108), I demonstrated that the available data on the LPE are consistent with a criterion shift account: in signal detection terms,

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low prevalence induces a conservative bias, but does not change sensitivity. Here I compile the published data on high prevalence and compare the high prevalence effect (HPE) to the LPE. The summary effect sizes for sensitivity (d') were both negligible (LPE: g = 0.04, 95% CI -0.21 to +0.29; HPE: g = 0.55, 95% CI -0.40 to +1.51). However, the effect sizes for criterion (c) were significantly negative for both the LPE (g = -2.44, 95% CI -3.11 to -1.77) and the HPE (g = -6.57, 95% CI -8.76 to -4.38), indicating that criterion was more conservative at lower prevalence and more liberal at higher prevalence. These findings support the idea that both the LPE and the HPE can be explained within a unified theoretical framework. I also present meta-regression analyses detailing how different stimulus types and observer populations modulate the results.

33.471 **The unique face-centered human strategy to search for people in the wild** Miguel P Eckstein[1](eckstein@psych.ucsb.edu), Thuyen V Ngo[2], B.S. Manjunath[2]; [1]Department of Psychological and Brain Sciences, University of California, Santa Barbara, [2]Department of Electrical and Computer Engineering, University of California, Santa Barbara

Introduction: When identifying a person from a video of a single individual, humans rely on face but also body information (e.g., Hahn et al., 2015). Here, we investigate search for a person in cluttered outdoor videos containing other distractor people. We investigated the eye movements and contributions to the performance by different features: bodies, heads, and faces. Critically, we ask whether the human utilization of features reflects differences in discriminative information content across features or a strategy particular to humans. Methods: Sixty observers searched for two people (person 1, person 2, none) among distracting people in cluttered outdoor videos (6 sec.) in four conditions: intact, headless, faceless, and bodiless people. To objectively quantify the contributions to person identification by different features we utilized a foveated ideal observer (FIO; Peterson & Eckstein, 2012) and a deep neural network (DNN; He et al., 2016). FIO and DNN identification performance were obtained for still images from the videos. The DNN performance was also obtained for data that was pre-processed with a foveated system fixated on faces (DNN-FOV). Results: When the head was present in the videos human fixations heavily concentrated on the face. Observer identification performance degraded the most when removing faces or heads (intact = 0.78 ± 0.05 vs. faceless = 0.55 ± 0.07; headless = 0.52 ± 0.06) but much less without the bodies (0.73 ± 0.05). In contrast, FIO, DNN and DNN-FOV performance degraded as much or more for the bodiless condition. In a separate experiment, forcing humans to fixate away from the faces degraded accuracy. Conclusion: Eye movements to faces during person search serve to optimize accuracy. The face-centered human strategy is not related to higher information content in faces but likely arises as a byproduct of the importance of faces for other evolutionary critical tasks.

33.472 **Does this grab your attention? A comparison of attention and memory resources deployed during search for artificial and real world objects.** Christopher M Jones[1](cj968655@gmail.com), Lauren H Williams[1], Trafton Drew[1]; [1]University of Utah

Current theories of visual search posit that search is guided by the maintenance of an attentional template of the search target. This template is thought to be maintained in working memory (WM) for novel targets and in long-term memory for repeated targets. In previous experiments this has been measured using the Contralateral Delay Activity (CDA: Vogel & Machizawa, 2004). The CDA reflects the maintenance of information in visual WM. As targets repeat, the CDA decreases in amplitude, suggesting decreased reliance on the attentional template in WM (Carlisle et al. 2011). We wondered whether this decrease varies as a function of object type. In these experiments, electroencephalographic activity was recorded while participants completed a visual search task in which they searched for a target repeated for six trials in a row. In Experiment 1, the decrease in CDA amplitude across repetitions was compared between artificial stimuli (Landolt Cs) and images of real-world objects. The CDA amplitude decreased across trials at the same rate for both real-world objects and Landolt Cs, suggesting that the two types of stimuli are similarly represented in WM despite differences in visual characteristics, semantic association and search difficulty. In contrast to the WM representation of the target, initial selection appears to be strongly modulated by object type. The amplitude of the N2pc (a component related to attentional selection) increased after the first target repetition when searching for objects, but did not increase across Landolt C repetitions. This was an unexpected result and was replicated in a separate experiment. It appears that repeated exposure to real-world target objects sharpens selection mechanisms associated with these objects. This suggests that search for real-world objects engages attention in a fundamentally different manner than search for artificial stimuli even though both are similarly represented in WM.

Acknowledgement: UROP, BHS

33.473 **Effects of Saccade Magnitude, Spatial Frequency, and Ocular Artifact Removal on the Fixation-related Lambda Response** Anthony J Ries[1](anthony.ries@us.army.mil), David Slayback[1], Jon Touryan[1]; [1]Human Research and Engineering Directorate U.S. Army Research Laboratory Aberdeen Proving Ground, MD 21005

Fixations provide natural and unique time-locking events in the electroencephalographic (EEG) record enabling the measurement of fixation-related potentials (FRPs). The most prominent FRP component is commonly referred to as the lambda response, a positive deflection over occipital electrodes peaking 80-100 ms post fixation, reflecting afferent input to visual cortex. Prior work suggests the lambda response may be a useful index of visual information processing; however, there are considerable gaps in our understanding of this response that need to be addressed before this can be realized. While it is know that the lambda potential is responsive to feature-based manipulations and the size of the preceding saccade, prior research has not adequately controlled for these manipulations in free viewing paradigms, nor has the potential interaction of these effects been investigated. The current experiment addresses these concerns by systematically manipulating spatial frequency in a free view task requiring a range of saccade sizes. Importantly, when estimating the FRPs we evaluate how removing independent components (IC), associated ocular motion artifacts, affects lambda response amplitude. Our results indicate that removing these ocular ICs did not significantly affect the amplitude of this occipital potential. Moreover, the results showed that spatial frequency and saccade magnitude each produce significant effects on lambda amplitude, where amplitude decreased with increasing spatial frequency and increased as a function of saccade size. The amplitude differences between spatial frequencies were maintained across all saccade magnitudes suggesting these effects are produced from distinctly different and uncorrelated sources.

33.474 **Fixation Selection for Categorical Target Searches in Real-World Scenes** Nicholas Kleene[1](nkleene88@gmail.com), Melchi Michel[1]; [1]Rutgers University

Bayesian observer models have seen widespread success in predicting fixation locations for visual search tasks using artificial stimuli, such as Gabors in 1/f noise (Najemnik & Geisler, 2005), but comparatively little in predicting fixation locations for searches for natural categorical targets in real-world scenes. Critically, previous approaches have not accounted for the effects of foveation nor implemented decision rules to select a sequence of fixations. Here we present a Bayesian model of fixation selection in visual search tasks using natural images. The model used two known sources of information to select fixations: scene context and the spatial distribution of target-like features (the target-relevant feature distribution). Scene context functions as a prior over potential target locations, while the target-relevant feature distribution is used to compute the likelihood function. In line with previous approaches (Torralba, Oliva, Castelhano & Henderson, 2006; Ehinger, Hidalgo-Sotelo, Torralba & Oliva, 2009), we use GIST features to characterize scene context and we use Histograms of Oriented Gradients (Dalal & Triggs, 2005) to characterize target-relevant features. In addition, we account for the effects of foveation and combine these information sources with a sequential Bayesian updating framework (similar to Najemnik & Geisler, 2005). Using scene context or the target-relevant feature distribution alone, our model performs quite well (greater than 90% localization performance and greater than 95% classification performance, respectively). To compare our model's fixation selections, we tested human observers on a pedestrian search task in natural images. Before the search task, visibility maps were measured for each human observer. These visibility maps were used to degrade the target-relevant feature information in our model simulations, replicating the effects of foveation. We compare the model's selected

fixations with those of human observers and discuss the implications regarding what information humans should use, and how they should combine it when selecting fixations.

33.475 **Display repetitions do not improve search efficiency in parallel search tasks.** Gavin JP Ng[1](jng17@illinois.edu), Simona Buetti[1], Alejandro Lleras[1]; [1]University of Illinois at Urbana-Champaign

Recently, Buetti, Cronin, Madison, Wang, and Lleras (2016) found that reaction times increase logarithmically as a function of set size in fixed-target efficient search tasks. The authors proposed that these logarithmic functions arise because stage-one is a parallel, unlimited capacity, and exhaustive process. In stage-one, evidence is accumulated at each location in the display to determine whether the location is likely to contain the target or not. Once a location reaches threshold, it can be confidently rejected as unlikely to contain the target. These locations are then excluded from further processing. Critically, during this early stage, all the locations receive some degree of processing simultaneously, which means that this stage provides an opportunity for a “map” of the display configuration to be encoded into memory. Here, we examined whether display configurations viewed under these efficient search conditions can produce the search benefit known as Contextual Cueing. In this phenomenon, participants are presented with up to 12 repeated display configurations that perfectly predict the target location (not its identity). Participants come to implicitly learn the association between the display configuration and the target location, allowing them to find targets faster in repeated compared to novel display configurations. Typically, Contextual Cueing experiments involve a serial, self-terminating (stage-two) search. Here, we varied set size (1, 4, 10, 20, and 32) in an efficient search task. RTs showed the same logarithmic increase as a function of set size in both new and repeated displays. That is, people processed both display types with equal efficiency. Further, we found no evidence of Contextual Cueing. Interestingly, almost all participants noticed that displays were repeated during the experiment. Thus, we found a dissociation between efficient search (no Contextual Cueing, but awareness of display repetitions) and inefficient search (Contextual Cueing present, but no awareness of display repetitions).

33.476 **Is there a relationship between object recognition ability and visual search efficiency?** Jing Xu[1](jingxu9@illinois.edu), Alejandro Lleras[1], Simona Buetti[1]; [1]Psychology Department, LAS, University of Illinois

Richler, Wilmer, and Gauthier (2017) proposed that object recognition ability can be understood as a specific type of cognitive ability, distinct from other general abilities like IQ and working memory. To measure this ability, the authors developed the Novel Object Memory Test (NOMT). Participants are presented with novel objects and must then identify the specific object amongst objects that closely resemble it. Performance on this test provides a good psychometric evaluation of an individual’s ability to compare visual objects to a template momentarily stored in working memory and has high reliability across novel categories. Recently, Buetti, Cronin, Madison, Wang, and Lleras (2016) proposed that parallel visual search with a fixed target is also accomplished by comparing in parallel a target template to objects in a scene. If the objects are sufficiently dissimilar from the target, this comparison allows the observer to reject non-target objects in parallel and to quickly identify the location containing the target. Buetti et al. demonstrated that the logarithmic slope observed in fixed-target parallel search tasks can be interpreted as an index of the time it takes observers to reject a non-target item. Using an individual differences approach the current study investigated whether there is a relationship between the object recognition ability (assessed by the NOMT for two novel categories) and individuals’ ability to reject non-target items in parallel in an efficient visual search task. Items were placed around fixation at three different eccentricities (spacing minimized crowding) and were cortically magnified to equate accumulation rates. The target was presented with 0, 1, 5, 15, 31 non-targets. Subjects differed in their logarithmic efficiency (range: ~10-60 ms/log unit) and they also differed in their NOMTs scores (range: ~40-90% correct), yet we found no strong evidence of a meaningful correlation between these two measures.

33.478 **Are rejected distractors maintained in working memory? Evidence from the Contralateral Delay Activity** Lauren H Williams[1](lauren.h.williams@utah.edu), Trafton Drew[1]; [1]Department of Psychology, University of Utah

The relationship between working memory (WM) and visual search has been heavily debated in the literature. Although behavioral results have been mixed, one proposed role of WM in search is to guide attention toward novel locations through the maintenance of previously rejected distractors (Peterson, et al., 2001). In previous research, we failed to find evidence for this relationship using the Contralateral Delay Activity (CDA) to measure the contents of WM during search for real world objects (Williams & Drew, 2017). However, distractor maintenance might only be necessary in search tasks with targets and distractors that have a high degree of feature overlap. In order to address this possibility, the current study used Landolt C stimuli rather than real world objects. On each trial, participants were shown a novel target for 1000 ms followed by an 800-1000 ms retention interval. The primary task was to indicate if the target was present (50%) or absent (50%) in a lateralized search display. The number of lateralized items in the search array varied between 2, 4, or 6. ERPs were time-locked to the onset of the search array, and the CDA was measured between 300-800 ms. The CDA is an index of the contents of WM and increases in amplitude with the number of items maintained (Vogel & Machizawa, 2004). Therefore, if previously rejected distractors are held in WM, the amplitude of the CDA should increase with the number of distractors in the search array. This pattern should be particularly evident during target absent trials because each item needs to be evaluated before a response can be made. However, there were no differences in the CDA amplitude across set sizes. Together, these studies suggest that, regardless of the level of similarity between targets and distractors, rejected distractors are not maintained in WM during search.

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Attention: Models, methods and multiple targets

Sunday, May 20, 2:30 - 4:15 pm, Talk Room 1

Moderator: Iris Wiegand

34.11, 2:30 pm **Modeling the neural underpinnings of attentional suppression as constrained by EEG and behavioral data** Chloe Callahan-Flintoft[1](ccallahanflintoft@gmail.com), Brad Wyble[1]; [1]Pennsylvania State University

A major challenge of perception is the decision of what to attend to. What makes information "important" is thought to be a combination of goal-defined top-down control (e.g. searching for a highway sign while driving), and stimulus driven bottom-up salience (e.g. a deer suddenly appearing in front of your car). Mediating between these two competing requirements is a major challenge that the brain meets by allowing stimuli to compete for attention, a competition that is ultimately resolved by enhancing some information while suppressing others. However there is mixed evidence for how this suppression occurs. Some studies show evidence for graded suppression in the immediate vicinity of a target (Mounts, 2000), while others show suppression specifically applied at the locations of salient distractors (Gaspelin et al., 2015). While these results may seem at odds with one another, they can be explained by a single underlying model. We present such a model that uses hierarchical neural circuits specifically adapted for rapid, parallel decision making about how to deploy attention across the visual field. Another crucial contribution of the model is elucidating the underlying causes of the neural correlates of attention such as the Pd. While the Pd is commonly thought to reflect distractor suppression, the model attributes its source to the suppression of locations in the visual field that did not win the competition for attention. Depending upon the rigidity of attentional control settings, the losing location could be that of the target or the distractor. Rigid control settings (feature search) more often result in the target winning whereas weaker settings (singleton search) frequently allow the distractor to win. Thus the model explains how task requirements determine behavioral and neural correlates of attentional capture. More generally, the model provides an intuition linking behavior and neural correlates to underlying mechanisms.

Acknowledgement: NSF

34.12, 2:45 pm **In pursuit of visual attention: SSVEP frequency-tagging targets in a smooth-pursuit paradigm** Peter de Lissa[1](peter.delissa@unifr.ch), Roberto Caldara[1], Victoria Nicholls[2], Sebastien Miellet[3]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg, Fribourg, Switzerland, [2]Department of Psychology, University of Bournemouth, United Kingdom, [3]School of Psychology, University of Wollongong, Australia

Road crossing contexts necessitate the spread of visual attention across varying locations of the visual field, which may have dire consequences if performed inadequately. Analyses of eye-movement patterns suggest differences in strategies employed by pedestrians of different developmental ages, where adults and older children tend to overtly monitor for the appearance of new cars while covertly monitoring existing cars as they move through their visual field. This pattern contrasts with younger children, who tend to follow moving cars with their eyes, neglecting to monitor for the appearance of new cars. The ability of adults to monitor cars with their covert visual attention is, however, mostly inferred by their performance in road-crossing tasks rather than specific evidence of divided visual attention. To determine whether there is an objective index of this division of visual attention in a road-crossing context, we combined a smooth pursuit eye-movement paradigm with a frequency-tagging EEG technique, whereby visual attention was measured through synchronised neural responses to the periodic flicker (30 Hz) of an overtly attended moving stimulus. To induce a division of visual attention, half of the blocks involved only one car moving across the screen, while the other half involved the possibility of a second car appearing during the trial. Event-related spectral perturbation analyses of the 30 Hz oscillations at the occipital lobe showed a clear decrease in synchrony at specific times in the trial when visual attention was divided by the need to monitor for the appearance of new stimuli, relative to when attention was undivided. The co-registration of EEG with eye-movements in a smooth-pursuit paradigm revealed a unique neural signature of divided attention during a simulated road-crossing context. This neural marker could thus be used in all populations as an index of effective information sampling for road crossing.

Acknowledgement: Funding for this project was provided by the Swiss National Science Foundation, grant number- 100019_156541

34.13, 3:00 pm **Probabilistic perceptual landscapes** Andrey Chetverikov[1](andrey@hi.is), Gianluca Campana[2,3], Árni Kristjánsson[4]; [1]Visual Computation Lab, Center for Cognitive Neuroimaging, Donders Institute for Brain, Cognition and Behavior, Nijmegen, The Netherlands, [2]Dipartimento di Psicologia Generale, Università degli Studi di Padova, Padova, Italy, [3]Human Inspired Technology Research Centre, Università degli Studi di Padova, Padova, Italy, [4]Laboratory for Visual Perception and Visuomotor Control, Faculty of Psychology, School of Health Sciences, University of Iceland, Reykjavik, Iceland

How do humans represent the visual world? Previous work suggests that observers' representations are probabilistic and incorporate the uncertainty associated with stimuli. However, this work was usually limited to simple stimuli (e.g., a single grating) arguably rare in the real world. Recently, we found that probabilistic representations of distractors in odd-one-out visual search follow the shape of the probability distribution used to generate the distractors. Here we demonstrate how this effect allows the decoding of the representations of complex stimuli, such as an array of lines with orientations drawn from different probability distributions. We show how the distributions of features by locations in a physical world are transformed into probabilistic landscapes in observers' minds. We collected observers' responses during odd-one-out orientation search with distractors generated from two different distributions. These distributions were either mixed randomly, separated into different halves of the visual field, or presented in stripes. Trials were organized in sequences. Each "prime" sequence (during which the distractor distributions stayed the same) was followed by test trials with varying similarity between test target and prime distractors. We then estimated via bootstrapping the most expected distractor orientation corresponding to the slowest response times in test trials at different locations. Thus, we obtained 2D (horizontal position and orientation) and 3D (horizontal and vertical positions and orientation) maps showing observers' probabilistic representations. The representations generally followed the generative probability distributions, with some exceptions: even when the distributions had sharp boundaries, representations were smoothed, with intermediate features expected on borderline locations. We introduce a new method allowing decoding of representations (including associated uncertainty) of complex heterogeneous stimuli showing that they are encoded probabilistically just as simpler stimuli are. This provides strong support for the idea of hierarchical probabilistic representations in the brain and shows how detailed statistics of the environment can be acquired.

Acknowledgement: Icelandic Research Fund grant #173947051 Radboud Excellence Initiative

34.14, 3:15 pm **Subjective inflation in the unattended periphery in a naturalistic environment** Brian A Odegaard[1](odegaard.brian@gmail.com), Musen Li[2], Hakwan Lau[1,3,4]; [1]Department of Psychology, University of California-Los Angeles, [2]Department of Industrial Engineering, Tsinghua University, China, [3]Brain Research Institute, University of California-Los Angeles, [4]Hong Kong University, Hong Kong

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Do we perceive fine details in the visual periphery, or do we overestimate how much we see outside the center of the visual field? While some researchers claim the former (Haun, Tononi, Koch, & Tsuchiya, 2017; Kaunitz, Rowe, & Tsuchiya, 2016; Vandenbroucke et al., 2014), phenomena such as inattentional blindness and change blindness provide evidence for the latter. Interestingly, recent work has consistently replicated one finding which relates to this question: observers tend to use liberal perceptual criteria when detecting items at unattended or peripheral locations (Rahnev et al., 2011; Solovey et al., 2015), with a tendency to report seeing items that were never presented. These experiments used very simple stimuli in an artificial environment; here, we asked whether observers would exhibit similar liberal detection criteria when making judgments about visual items in a more natural environment. Using an innovative game-building engine, we created a task where subjects had to drive a car down a city street and make judgments about attributes of pedestrians' clothing in the visual periphery. Results from our first experiment demonstrated than when participants were asked about whether one specific color was presented on an individual in the periphery, they used liberal detection criteria and exhibited relatively high numbers of false alarms, similar to previous investigations. Following this first experiment, we conducted a second study which varied the color that subjects were asked to detect on every trial. Results from this experiment showed that when the color to be detected changed across trials, observers actually exhibited relatively conservative detection criteria, with few numbers of false alarms, but higher numbers of misses. These results can be quantitatively characterized using a detection theoretic formal model, and provide evidence of interactions between task demands and the criteria subjects use to make perceptual judgments.

Acknowledgement: AFOSR

34.15, 3:30 pm **Hybrid visual and memory search is preserved in older age** Iris Wiegand[1,2,3](wiegand@mpib-berlin.mpg.de), Jeremy M Wolfe[1]; [1]Visual Attention Lab, Brigham & Women's Hospital, Harvard University, [2]Max Planck UCL Centre for Computational Psychiatry and Ageing Research, [3]Center for Lifespan Psychology, Max-Planck Institute for Human Development

Attention and long-term memory (LTM) are considered to be prone to age-related decline. Attentional control and episodic recollection are more vulnerable than bottom-up selection and familiarity-based recognition. Visual attention and LTM can be manipulated and measured within a "hybrid search" task, in which observers look through visual displays for instances of any of several types of targets held in memory. Hybrid search thereby resembles many real-world search tasks and constitutes a promising tool to assess hallmarks of normal cognitive aging. We compared younger and older observers in several hybrid search tasks. In Experiment 1, observers memorized 1-16 photorealistic objects and then searched for these targets in visual displays containing 1-16 new (unfamiliar) distractor objects. Apart from general slowing of response time (RT), older observers produced linear RT x visual setsize and logarithmic RT x memory setsize functions very similar to younger observers. Notably, relative costs of increasing visual and memory load were comparable across age groups, indicating no age-related decline. In Experiment 2, we prevented familiarity-based recognition of targets by presenting targets and distracters with the same frequency over search trials. Surprisingly, distracter-familiarity did not affect RT functions or error rates in either age group, indicating that hybrid search is not based on item-familiarity. Again, the only effect of age was generalized slowing. In Experiment 3, items were targets in one context, but incorrect lures in another context. RTs and errors indicated modest interference by lures; however, again, these costs were comparable between age groups. Our results show that hybrid search is preserved in older age, even though attentional demands are relatively high and recollection from episodic memory is involved. This contradicts contemporary theories of cognitive aging and raises questions about standard neuropsychological measures of age-related decline, particularly with regard to predicting elderly's performance in real-world search task.

34.16, 3:45 pm **Single-target visual search tasks provide only a snap-shot of attentional orienting: New insights from visual foraging tasks.** Arni Kristjansson[1](ak@hi.is), Ian M Thornton[2], Tómas Kristjansson[1]; [1]Icelandic Vision Laboratory, University of Iceland, [2]Department of Cognitive Science, University of Malta

The assessment of the functional properties of visual attention has in past decades been dominated by single-target visual searches, where observers search for a target among distractors, and the search ends when the target is found. But our goals from one moment to the next are unlikely to involve only a single target, and recently, paradigms involving visual foraging for multiple targets have been used to investigate visual attention. Set-size effects in single-target visual search tasks partly form the foundation of many theories of visual search. We therefore manipulated set-size in a visual foraging task, involving both "feature" and "conjunction" foraging. The target selection times during foraging revealed specific components of the foraging pattern: 1) a 'cruise phase' where observers select targets very rapidly, far more quickly than typical response times in visual search. 2) During conjunction foraging there were distinct mid-peaks that reflect switches from one target-type to the other 3) Finally there were end-peaks in selection times during both feature and conjunction foraging reflecting slowed responses when observers tap the last target. Strikingly, these end peaks replicate well-known set-size patterns seen during single-target visual search tasks, showing how single-target tasks only provide a snapshot of visual attention. Our foraging results reveal how dominant single-target visual search paradigms may only scratch the surface of attentional function, and that typical single-target search patterns are only seen for a limited part of the foraging pattern, in particular, the last target. Our results show how single-target visual search tasks vastly undersample the operation of visual attention, providing only a snap-shot of attentional function and this limited information is bound to be reflected in theoretical accounts based on such tasks.

Acknowledgement: Icelandic Research Fund (IRF) Research fund of the University of Iceland

34.17, 4:00 pm **Modelling complex perception-action choices** Ruohan Zhang[1](zharu@utexas.edu), Jake A Whritner[2], Zhuode Liu[1], Luxin Zhang[3], Karl S Muller[2], Mary M Hayhoe[2], Dana H Ballard[1]; [1]Department of Computer Science, The University of Texas at Austin, [2]Center for Perceptual Systems, The University of Texas at Austin, [3]Department of Intelligence Science, Peking University

In many contexts, such as reading and sandwich making, the function of gaze is readily interpretable. However, in other contexts (e.g., game playing) the underlying task structure has no ready interpretation. The development of Convolutional Neural Nets (CNNs) has led to breakthroughs in models of human pattern recognition. Here we show their potential for predicting the linkage between gaze and action choices as a way of revealing the underlying task structure in complex behavior. We collected records of actions and gaze using an EyeLink 1000 eye tracker, while participants played eight Atari games in the Arcade Learning Environment. This dataset was used to train two deep CNNs, which we refer to as the Gaze Network and the Policy Network. The former is trained on human gaze data and learns to accurately predict observed gaze positions given the image. The Policy network learns to predict actions (such as firing or evasion) given the image and gaze. The result is that incorporating the output of the Gaze Network into the Policy Network significantly improves the accuracy of human action prediction. By incorporating an attention model that extracts the features that are most important for the task, the learning agent is able to better imitate the human demonstrator's behaviors. The visual attention model also enables the agent to learn better policies, resulting in higher game scores than previous networks. Those networks were trained to predict behaviors demonstrated by human experts using image data, but had no overt attention cues. Our results demonstrate that adding the gaze data greatly improves predictions accuracy (up to 16%). Consequently, the approach explored here has potential for modeling complex visually guided behavior and discovering the underlying task structure.

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Binocular Vision: Neural mechanisms

Sunday, May 20, 2:30 - 4:15 pm, Talk Room 2

Moderator: Frederick Kingdom

34.21, 2:30 pm **Interocular normalization in monkey primary visual cortex** Alexandre Reynaud[1](alexandre.reynaud@mail.mcgill.ca), Sébastien Roux[2], Sandrine Chemla[3], Frédéric Chavane[2], Robert F Hess[1]; [1]McGill University, [2]CNRS & Aix-Marseille Université, [3]CNRS & Université Paul Sabatier Toulouse III

The slightly different signals coming from the two eyes allow our brain to compute a tridimensional representation of the visual world. The monocular inputs reach the cortex in layer 4 where they are segregated and form ocular dominance domains. Then they are first combined by binocular neurons in layers 2/3. At the surface of the cortex, ocular dominance domains are spatially organized in so-called ocular dominance stripes. Studying how the information coming from the two eyes is integrated at the mesoscopic scale is of relevance. For this purpose, we used optical imaging in anesthetized monkey to analyze how these signals are integrated and summed at the population level in V1. Ocular dominance maps were obtained with standard intrinsic optical imaging procedures. Dichoptic interactions were studied with voltage-sensitive dye imaging (VSDI) using a frequency-tagging paradigm. Visual stimuli of different contrasts were presented at 6Hz and 10Hz to the left and right eye respectively, separately or simultaneously with a passive 3D monitor. The frequency analysis of the evoked response was used to identify the contribution of each eye. We observed that the population activity in V1, elicited by the stimulation of one eye, is suppressed by a dichoptic stimulation. This signal integration could be modeled by an interocular normalization model of population activity. These approach and model represent a necessary step in understanding how the binocular balance could be affected by deprivation such as short-term monocular occlusion.

Acknowledgement: This work was supported by the French National Research Agency (ANR BalaV1 number ANR-13-BSV4-0014-02), an ERA-NET NEURON grant (JTC 2015) and the Quebec Fund for Research (FRQS Vision Health Research Network networking grant 3738-2016)

34.22, 2:45 pm **Cocktails anyone? Revisiting ocular dominance and opponent cortical processing** Daniel Y Tso[1](tsod@upstate.edu), Ronald Miller[1], Momotaz Begum[1]; [1]Dept. Neurosurgery, SUNY Upstate Medical University

The traditional view of the interocular interactions in setting up ocular dominance in primate V1 is one of competition between the two eyes, at least during development if not also ongoing. A re-examination of ocular dominance (OD) data from optical imaging studies suggest an interocular process that seeks to maintain a set level of left/right eye opponency (an L-R signal) atop other ongoing cortical activity. Optical imaging of OD columns (ODCs) is performed by acquiring sets of V1 images during left eye (L), right eye (R) stimulation, and no stimulation (blank). The image data is analyzed to yield an ODC map with an L-R calculation. Invariably the OD (L-R) image yields a far "cleaner" map of the ODCs than the "single condition" maps provide (e.g. L-blank). Extracting a line profile across the ODCs in comparison to a line profile of the L or R maps confirms a smooth, nearly sinusoidal OD signal while the L or R profiles appear extremely noisy with the OD signal often buried. The calculation of L-R is equivalent to removing the "cocktail blank" signal, i.e. removing common mode cortical activity signal and other artifacts, beyond those removed with blank subtraction. These results imply an interocular process that provides a robust OD (L-R) signal despite substantial local variances in cortical activity. This notion is supported by short-term monocular deprivation (STMD) experiments in which a 1-2 hour monocular deprivation yields a disruption of interocular balance and monocular gains lasting an hour. Yet immediately following STMD, the OD(L-R) signal visualized by optical imaging "bounces back" to near normal in amplitude and form even while each eye's activity has not returned to baseline. The implication is that interocular/binocular V1 circuits strive for a robust OD(L-R) signal despite local and monocular perturbations, perhaps a by-product of maintaining proper interocular balance.

34.23, 3:00 pm **A hierarchical Bayesian model for inferring neural tuning functions from voxel tuning functions** Patrick Sadil[1](p-sadil@gmail.com), David E. Huber[1], John T. Serences[2], Rosemary A. Cowell[1]; [1]Psychological and Brain Sciences, College of Natural Sciences, University of Massachusetts, Amherst, [2]Department of Psychology, University of California, San Diego

It is tempting to infer the behavior of individual neurons from the behavior of individual voxels in an fMRI experiment. For instance, voxel tuning functions (VTFs) measure the magnitude of the BOLD response to a range of stimulus features (e.g., orientation), producing results that resemble individual neural tuning functions (NTFs) from single-cell recordings – like a simple cell in V1, a voxel will prefer a particular orientation. However, a voxel likely reflects a mixture of different kinds of neurons with different preferred orientations. Taking a GLM approach to this problem, forward encoding models (e.g., Brouwer and Heeger, 2009, 2011) specify the strength of different neural sub-populations (e.g., neurons preferring different orientations) for each voxel. However, these models cannot identify changes in the shape of the neural tuning function because they assume a fixed NTF shape. For instance, these models could not identify whether the NTF sharpens with perceptual learning. To address this limitation, we developed a hierarchical Bayesian model for inferring not only the relative proportions of neural sub-populations contributing to a voxel, but also the shape of the NTF and changes in NTF shape. To test the validity of this approach, we collected fMRI data while subjects viewed oriented gratings at low and high contrast. We considered three alternative forms of NTF modulation by stimulus contrast (additive shift, multiplicative gain, bandwidth sharpening). To the naked eye, the VTFs revealed an additive shift from low to high contrast. However, the hierarchical Bayesian model indicated that this shift was caused by multiplicative gain in the underlying NTFs, in line with single cell recordings. Beyond orientation, this approach could determine the form of neuromodulation in many fMRI experiments that test multiple points along a well-established dimension of variation (e.g., speed of motion, angle of motion, isoluminant hue).

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34.24, 3:15 pm **Levelt's propositions examined at the level of mutually inhibiting pyramidal cells in primary visual cortex** Naoki Kogo[1](naoki.kogo@gmail.com), Felix Kern[2], Thomas Nowotny[3], Raymond van Ee[4], Richard van Wezel[1], Takeshi Aihara[5]; [1]Biophysics, Donders Institute for Brain, Cognition and Behaviour, Radboud University, [2]University of Sussex, School of Life Sciences, Sussex Neuroscience, [3]School of Engineering and Informatics, University of Sussex, [4]Brain and Cognition, University of Leuven, [5]Graduate School of Brain Sciences, Tamagawa University

We established an in vitro neural recording system combined with computerized connection mediated by model neurons and synapses. With this "dynamic clamp" system, a mutual inhibition circuit between (real) pyramidal cells was constructed. By activating both pyramidal cells simultaneously, we were able to evoke bi-stable activity. Using this system, we ran paradigms that are equivalent to the ones by Levelt (1967, British Journal of Psychology (58) 143-145) to investigate the dynamics of binocular rivalry. The paradigm for Levelt's 4th proposition was modeled by increasing the depolarization currents to both pyramidal cells at the same time. The bi-stability of the pyramidal cells showed increased reversal frequencies in agreement with the Levelt's 4th proposition. The paradigm for the 1st to 3rd propositions was modeled as follows. First, the depolarization currents were adjusted to evoke action potentials at approximately 10Hz. Second, with the mutual connections turned on, the depolarization currents that evoke bi-stable activity with equal dominance between the two neurons were estimated ("standard currents"). Third, the depolarization current to one of the two pyramidal cells was systematically changed. The results were as follows. (1) The increase of the current in one cell caused an increase of the dominance of the cell. (2) The average dominance duration of the dominant cell increased with the increase of the difference of the current from the standard current. (3) The reversal frequency decreased with the increase of the difference of the current from the standard current. The result (1) corresponds to Levelt's 1st proposi-

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tion but (2) and (3) do not to his 2nd and 3rd propositions, respectively. However, these results (1)~(3) remarkably correspond to the modified propositions by Brascamp and Klink (2015, Vision Research (109) 20-37). This suggests a fundamental role of mutual inhibition circuit in the dynamics of bi-stable perception.

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34.25, 3:30 pm **Adaptation to interocular decorrelation** Frederick Kingdom[1](fred.kingdom@mcgill.ca), Ben J Jennings[2], Mark A Georgeson[3]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, Canada, [2]McGill Vision Research, Department of Ophthalmology, McGill University, Canada, [3]School of Life & Health Sciences, Aston University, UK

Aim. Humans are sensitive not only to interocular positional disparities, the basis of stereopsis, but also disparities in contrast or hue. Here we ask whether the mechanisms for detecting such disparities are adaptable. Evidence of adaptability would support the idea that there are dedicated channels for detecting interocular disparities in contrast or hue. Here we term such disparities 'interocular decorrelations'. Methods. Stimuli were horizontally-oriented multi-spatial-frequency sine-wave luminance gratings, subject to interocular differences in their component sine-wave phase Ø. Observers adapted to various Ø, specifically correlated (Ø= 0o), uncorrelated (Ø = 90o) and anticorrelated (Ø = 180), as well as to monocular patterns (adaptor to just one eye) and to a blank screen (the no-adaptor condition). During the test period observers discriminated between a correlated pattern and one with a Ø>0 that was adjusted by a staircase procedure that converged on 79% correct detections. Ø values were then converted to an index of interocular decorrelation (ID) that ranged from 0-1 so that psychometric functions could be fitted to the proportion correct data and threshold IDs with bootstrap errors estimated. Results. ID thresholds for the no-adaptor and correlated adaptor conditions were not significantly different, but thresholds increased significantly as a function of adaptor ID, by approximately a factor of 6 when going from correlated (ID=0) to anticorrelated (ID=1) adaptor conditions. Thresholds were higher for the uncorrelated compared to monocular adaptors (even though both had an ID of 0.5). The difference between the monocular and uncorrelated adaptor was accounted for when the ID values were converted into interocular RMS contrast differences. Conclusion. Interocular decorrelation is an adaptable dimension of vision, likely mediated by the binocular differencing channel posited in previous studies.

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34.26, 3:45 pm **Visual dominance for darks increases in amblyopia.** Carmen Pons[1](Carmen.Pons.T@gmail.com), Reece Mazade[1], Jianzhong Jin[1], Mitchell Dul[1], Qasim Zaidi[1], Jose-Manuel Alonso[1]; [1]Department of Biological and Visual Sciences, SUNY College of Optometry, New York, NY

We have previously shown that luminance/response saturation in visual cortex is more pronounced for luminance increments (ON responses) than decrements (OFF responses) (Kremkow et al., 2014). Moreover, we showed that the pronounced ON luminance/response saturation causes an enlargement of light stimuli and enhances neuronal size suppression, making visual responses at low spatial frequencies weaker for lights than darks (Pons et al., 2016). Because optical blur reduces high spatial frequencies in the image, it should affect more the visual salience of lights than darks. Therefore, if optical blur is present during brain development, it should make cortical responses more dark dominated. To test our hypothesis, we measured the visual salience for light and dark stimulus in 19 amblyopic adults that experienced sustained optical blur early in life. Consistent with our hypothesis, we found that amblyopic subjects were more accurate and faster at detecting dark than light squares on a noisy background (Komban et al., 2011) and that the advantage for darks was more pronounced in the amblyopic eye than in the fellow eye (average dark-light difference in percent correct, amblyopic: 14.69±2.63 vs fellow: 2.81±0.67%, $p < 0.001$; reaction time, amblyopic: 1.82±0.29 vs fellow: 1.35±0.15 sec, p=0.03; two-sided Wilcoxon tests, n=19 subjects). Moreover, the differences between amblyopic and fellow eyes in dark dominance were strongly correlated with the severity of amblyopia ($R2=0.8$, $p < 0.001$). Performance in the visual acuity task was also lower for lights than darks in the amblyopic eye, but unlike the results for the visual salience task, the difference was not significantly larger than in the fellow eye (average dark-light accuracy difference, amblyopic: 17.37±3.12 vs fellow: 13.63±3.95%, p=0.77, two-sided Wilcoxon test, n=7 subjects). These results confirm our prediction that dark dominance for visual salience is increased in amblyopia and that sustained optical blur affects ON/OFF response balance during brain development.

Acknowledgement: EY027361

34.27, 4:00 pm **Stereo perimetry reveals a foveal impairment of stereopsis in amblyopia.** Saeideh Ghahghaei[1](saeideh@ski.org), Preeti Verghese[1]; [1]The Smith-Kettlewell Eye Research Institute

Amblyopia is associated with suppression in the central visual field. It has been proposed that in cases of anisometropia or small misalignment, there may be peripheral fusion that can serve as the basis for stereopsis (Siretanu & Fronius, 1981; Harrad, 1996). Here, we used a novel stereo perimetry method to test this conjecture. We measured stereopsis in the fovea and the periphery using a method analogous to perimetry. The observer maintained gaze at a fixation point, while keeping nonius lines aligned, and detected whether a target was presented in front of or behind the fixation plane. The target could appear on the cardinal or diagonal axes, at eccentricities of 0, 1.25, 2.5, 5, and 10 degrees from fixation, with size m-scaled for eccentricity (1° X 1° at fovea). Targets were presented at a large disparity step (10 or 15 arc min) for 1 sec. The inter-trial-interval was 3-4 seconds. Viewing distance was 40 cm. The display was made up of full-field dynamic random dots updated every 500 ms to minimize monocular cues. We tested 4 amblyopic participants (1 with anisometropia, 3 with strabismus), 2 participants with micro-strabismus, and 4 controls. For controls, the stereo perimetry map for depth discrimination showed high accuracy across the visual field. Our strabismic observers were unable to detect depth at any of the eccentricities we tested. For observers with anisometropia or micro-strabismus, stereo perimetry showed that depth discrimination was impaired specifically in the foveal and parafoveal regions (up to 5 degree eccentricity depending on the participant). Thus, our stereo perimetry technique demonstrates that when stereopsis is present in amblyopia, it is mediated by the periphery. This supports previous studies that suggest that coarser-scale mechanisms may survive small misalignment and the monocular blur associated with anisometropia (Giaschi et al, 2013; McKee et al, 2003).

Acknowledgement: NIH 1R01EY027390 to PV

Development and Disorders

Sunday, May 20, 5:15 - 7:15 pm, Talk Room 1

Moderator: Catherine Manning

35.11, 5:15 pm **Coherent motion evoked responses in school-aged children** Catherine Manning[1](catherine.manning@psy.ox.ac.uk), Gaia Scerif[1], Anthony M Norcia[2]; [1]Department of Experimental Psychology, University of Oxford, [2]Department of Psychology, Stanford University

Motion sensitivity increases during childhood, but little is known about the underlying neural correlates. Most studies investigating children's evoked responses have not dissociated direction-specific responses from those reflecting spatiotemporal luminance modulation. To isolate direction-specific responses, we presented coherently moving dot stimuli preceded by a 'boil' period of incoherent motion, to 102 children aged 6 to 12 years and 20 adults. Participants reported the direction of coherent motion (10%, 30%, 50% and 75% coherence) as quickly and accurately as possible, while high-density EEG was recorded. Using a data-driven approach, we identified stimulus-locked EEG components that were reliable from trial-to-trial. We found two components with distinct topographies: first, an early sensory component with a posterior topography, and second, a later, sustained positive component over centro-parietal electrodes, hypothesised to reflect the decision-making process. We divided the children by age into three groups of 34 and compared their component waveforms with the adult group. For all groups, evoked responses scaled with motion coherence. The components also showed clear developmental changes. In the first component, all groups showed a negativity peaking at ~300ms, like the previously reported coherent-motion N2. However, the children, unlike adults, showed an additional positive peak at ~200ms.

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The increasing positivity in the second component was steeper in older participants. To link these components with behavioral responses, we median-split trials by reaction time. In the adults and oldest children, the leading edge of the first component differentiated slow and fast trials from as early as ~200ms. The second component showed response-specific activity at 250-300ms in all groups apart from the youngest children. We suggest that children's development of coherent motion sensitivity is driven by the maturation of both early sensory and later decision-related processes. These findings will help to understand altered motion sensitivity in neurodevelopmental disorders.

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35.12, 5:30 pm **Gray Matter Thinning in Ventral Temporal Cortex from Childhood to Adulthood is Associated with Increased Myelination** Vaidehi S Natu[1](vnatu@stanford.edu), Jesse Gomez[2], Michael Barnett[3], Brianna Jeska[1], Zonglei Zhen[4], Evgeniya Kirilina[5], Carsten Jaeger[5], Siobhan Cox[1], Kevin S Weiner[1], Nikolaus Weiskopf[5], Kalanit Grill-Spector[1,2,6]; [1]Department of Psychology, Stanford University, CA, 94305, [2]Neurosciences Program, Stanford University, Stanford, CA 94305, [3]University of Pennsylvania, Philadelphia, PA, 19104, [4]Beijing Normal University, Beijing, China, [5]Max Planck Institute for Human Cognitive and Brain Sciences, Leipzig, 04103, Germany, [6]Stanford Neurosciences Institute, Stanford University, Stanford, CA 94305

Cortical thickness (CT) decreases from childhood to adulthood. However, the underlying mechanisms remain unknown. We tested two hypotheses using fMRI, quantitative MRI (qMRI), and diffusion MRI (dMRI) in 26 children (ages 5-12) and 27 adults. Pruning hypothesis: CT decreases from childhood to adulthood due to tissue reduction. Pruning predicts higher T1 relaxation time, measured with qMRI, and higher mean diffusivity (MD), measured with dMRI, in adults than children. Growth hypothesis: white/gray boundary shifts deeper into cortex due to increased myelination, making the cortex whiter in adulthood. Myelin growth predicts lower T1 and lower MD in adults than children. To test these predictions, we measured CT, T1, and MD in face-, character-, and place-selective regions in ventral temporal cortex of each participant and in the white matter neighboring each region. CT decreased from age 5 to adulthood in all category-selective regions. In white matter neighboring face- and character-selective regions T1 and MD also decreased with age. Similar decreases in T1 and MD were found in gray matter of face- and character-selective regions, with greatest changes in T1 in mid-cortical depths and in MD near the white/gray boundary. Importantly developmental decreases in T1 and MD were correlated with cortical thinning. In contrast, cortical thinning in place-selective cortex, was associated with developmental shifts in its location deeper into the sulcus, rather than changes in T1 or MD. Finally, we validated in-vivo measurements using Silver staining for myelin in adult ex-vivo brain slices. Consistent with in-vivo data showing lower T1 in face- than place-selective cortex, we found higher myelin content in face- than place-selective cortex in ex-vivo slices. Together, results suggest differential mechanisms of cortical thinning: development of face- and character-selective regions is associated with increased myelination, but development of place-selective cortex is associated with a shift in the region's location deeper into the sulcus.

Acknowledgement: NIH 1R01EY02391501A1, RO1EY02988-A1

35.13, 5:45 pm **Fiber-tract differences in people with congenital and acquired blindness** Katherine E.M. Tregillus[1](ktregillus@ski.org), Lora T Likova[1]; [1]The Smith-Kettlewell Eye Research Institute

Visual deficits can lead to differences in both the gray and white matter of the brain. Previous research has shown that there are connectivity differences (functional and structural) between sighted and blind individuals, with further differences in cortical activation between those with congenital and acquired blindness. The current study sought to determine the differences in major white matter tracts between congenitally blind and acquired blind participants, as well as to determine how they each differ from sighted subjects. Diffusion-weighted images were collected from three groups of participants: congenitally blind (CB), acquired blind (AB), and sighted controls with normal/corrected-to-normal visual acuity (SC). Each participant's data was processed using the Automated Fiber Quantification (AFQ) software package, which automatically groups fibers into a set of 20 fiber bundles using a two ROI-based approach (Yeatman et al., 2012). This method allows for accurate between-group comparisons without the use of co-registration algorithms, and thus tolerates greater variation at the level of individual fibers. For each subject, a partially-weighted mean fractional anisotropy (FA) was calculated at 100 nodes between the two ROIs for each fiber bundle. Comparisons of the FA values between the three groups showed several fiber bundles where the FA was greater for the AB group than for both the CB and sighted groups. Specific tracts that appeared to be particularly distinct in the AB participants included the cingulum, corticospinal, inferior fronto-temporal, and uncinate fasciculi bilaterally, as well as the right inferior longitudinal fasciculus. Interestingly, in fiber-tracts where all groups deviated from one another, the CB participants appeared to be more similar to the sighted group than to the AB group. These results suggest that the level of white matter reorganization in major fiber tracts is dependent on the onset of blindness.

Acknowledgement: LTL - NIH/NEI R01EY024056, KT - NIH/NEI 5T32EY025201-02

35.14, 6:00 pm **Motion cues aids perception of implied motion in amblyopia** Mahesh Raj Joshi[1](mahesh.joshi@sta.uwi.edu), Anita J Simmers[2], Seong Taek Jeon[2]; [1]Optometry Programme, Faculty of Medical Sciences, The University of the West Indies, [2]Optometry, School of Life Sciences, Glasgow Caledonian University

Deficits in global motion and global form perception have been reported in amblyopia. We examined how such deficits manifest in the visual function thought to be reliant on the interactions between these two processing mechanisms using the implied motion stimulus. A total of 13 amblyopes (8 strabismic and 5 anisometropic) and 6 visually normal controls monocularly discriminated the overall implied motion in dynamic Glass pattern (dGlass) in the presence of varying external noise. The results showed higher thresholds for strabismic (no noise, amblyopic = 3.61˚±1.50, fellow = 3.15±2.02) compared to anisometropic (no noise, amblyopic = 2.17˚±1.34, fellow = 2.43±1.72) and normal (no noise = 2.23˚±1.26) participants. The nested models were tested to estimate the relative contribution of internal noise and sampling efficiency parameters to explain the threshold change across different groups. The results showed no difference in performance for amblyopes compared to the normal controls (p's > 0.05). The thresholds for implied motion were then compared to global form (static Glass pattern; sGlass) and global motion (RDK). The nested models from all three stimuli were statistically compared to investigate how global motion and global form thresholds are different from the implied motion thresholds. The results showed no difference between thresholds for dGlass and RDK but higher thresholds for sGlass pattern best described the data, implying that the additional signal in dGlass might have improved amplyopic performance. Our result challenges the dorsal stream dysfunction hypothesis where motion processing is assumed to be more impaired than form processing in amblyopia.

35.15, 6:15 pm **Abnormal visual crowding and developmental dyslexia: Cause or effect?** Simone Gori[1](simone.gori@unibg.it), Sara Bertoni[2], Sandro Franceschini[2], Luca Ronconi[3], Andrea Facoetti[2]; [1]Department of Human and Social Sciences, University of Bergamo, [2]Department of General Psychology, University of Padua, [3]Cimec, University of Trento

For about 10% of people reading acquisition is extremely difficult, they are affected by a heritable neurodevelopmental disorder called dyslexia. Differences in perceiving the written word might be one of the causes of reading disabilities. Visual crowding is a universal phenomenon that impairs the recognition of stimuli in clutter, and there are some evidence that visual crowding is more severe in individuals with developmental dyslexia (DD) than in typical readers. The direct consequence of stronger crowding on reading is the inability to recognize letters when they are surrounded by other letters. However, the causal link between abnormal crowding and reading disorder is not yet clearly established. Here, we show multiple causal links between the visual crowding and learning to read. The results of four experiments in 128 participants reveal that: i) an abnormal visual crowding characterizes an unselected group of children

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with DD; ii) two action video game trainings that reduce visual crowding are able to improve reading skills in two unselected and independent children with DD, and; iii) pre-reading visual crowding longitudinally predicts future poor readers. Challenging the uni-causal phonological explanation of DD, our results demonstrate that learning to read depends also on an efficient visual neural network employed for the object recognition in clutter. These results provide new insights for early identification and possible prevention for DD.

35.16, 6:30 pm **Global motion and form processing and attention deficits in multiple child cohorts with neurodevelopmental disorders: Dorsal vulnerability or dorsal/ventral integration?**

Janette Atkinson[1,2](j.atkinson@ucl.ac.uk), Fleur Corbett[1], Elisa Fazzi[3], Serena Micheletti[4], Jessica Galli[3], Paola Mattei[4], Daniela Ricci[5], Giorgia Coratti[5], Maria Mallardi[5], Morag Andrew[6], Peter Sullivan[6], Jeremy Parr[7], Christine Montague-Johnson[6], Oliver Braddick[2]; [1]Faculty of Brain Sciences, University College London, UK , [2]Dept of Experimental Psychology, University of Oxford, UK, [3]Unit of Child Neurology & Psychiatry, Dept of Experimental & Clinical Sciences, University of Brescia, Italy, [4]Unit of Child Neurology and Psychiatry, ASST Spedali Civili, Brescia, Italy, [5]Pediatric Neurology Unit, Catholic University, Rome, Italy, [6]Dept of Paediatrics, University of Oxford, UK, [7]Institute of Neuroscience, Newcastle University, UK

We have previously described a cluster of deficits, across many genetic and acquired developmental disorders (from amblyopia to autism), in tasks related to dorsal stream networks, including poor motion coherence sensitivity, poor visuomotor integration and poor visual attention (Atkinson JOV, 2017). Here we examine and compare these deficits in four new cohorts of children aged 3-12 years, two following perinatal brain injury (PBI) and/or very preterm birth (< 33 weeks gestation) (total N=181), and two diagnosed with Developmental Coordination Disorder (DCD) (total N=65). Children were tested with the child-friendly 'Ball in the Grass' test of global motion and form coherence, and/or the ECAB (Early Child Attention Battery, including a new Italian adaptation) for gauging selective, sustained and attentional control, and (for DCD groups) the Movement-ABC assessing visuo-motor ability. We find that (a) marked motion coherence deficits are common in both DCD and PBI although in DCD these are a function of age; (b) approximately one third of PBI children show deficits in both global motion and form sensitivity; (c) attention deficits in PBI and preterm-born children are greatest in sustained attention; (d) individual differences in motion coherence are significantly correlated with ECAB in PBI, and both form and motion with visuomotor skills in DCD; (e) both coherence and attention deficits were greater than predicted from IQ in many PBI children. We relate these results to our MRI findings that children's motion coherence sensitivity is correlated with differential brain growth in specific parietal areas, visuomotor ability and numerical cognition (Braddick et al, J Cog Neuro 2016, Vision Res 2016). We will discuss our results in relation to interactions between dorsal and ventral streams, recent findings on changes in the connectome following preterm birth, and Duncan's multiple-demand network in the adult brain.

Acknowledgement: Leverhulme Trust, ESRC, Castang Foundation, Nutricia

35.17, 6:45 pm **Atypical visual motion prediction in autism spectrum disorder**

Woon Ju Park[1](woonju.park@rochester.edu), Kimberly B Schauder[1,2], Oh-Sang Kwon[3], Loisa Bennetto[2,4], Duje Tadin[1,4,5]; [1]Center for Visual Science, University of Rochester, [2]Department of Clinical and Social Sciences in Psychology, University of Rochester, [3]Department of Human Factors Engineering, Ulsan National Institute of Science and Technology, Ulsan, South Korea, [4]Department of Brain and Cognitive Sciences, University of Rochester, [5]Department of Ophthalmology, University of Rochester School of Medicine

Prediction is a fundamental brain function. We use past information to predict events ranging from positions of moving objects to social interactions. Recent work postulates impaired prediction as a global trait in autism spectrum disorder (ASD; Sinha et al., 2014). However, empirical evidence for this hypothesis is limited. Here, we test the integrity of motion prediction abilities in ASD. To better understand potential mechanisms of impairment, we comprehensively examined the factors known to be associated with motion prediction performance: the central-tendency bias and the relationship between smooth pursuit eye-movements and prediction errors. METHODS: Participants were 26 children and adolescents (ages 9-17) with ASD and 20 typically developing (TD) controls. The task was to predict the time-to-arrival of a moving object that disappeared behind an occluder. Across trials, we sampled the speed (constant; 10-20°/s), visible (8-18°) and occluded (0.5-20°) distances from uniform distributions, which together resulted in a range of visible (0.4-1.8s) and occluded (0.025-2s) durations. Prediction performance was evaluated using the bias and variability in responses. Smooth pursuit quality was characterized by pursuit gain (eye-/object-velocity). RESULTS: Individuals with ASD exhibited early prediction bias, where they responded, on average, 30ms earlier than the actual hitting time. This was most pronounced at longer occluded durations, and was not explained by the central-tendency bias observed in TD. They also showed atypically increased pursuit gain compared to controls during stimulus occlusion. Notably, pursuit quality was differentially linked to prediction performance in the two groups. Better smooth pursuit was associated with reduced prediction variability in TD and counterintuitively related to earlier prediction bias in ASD. CONCLUSIONS: Results demonstrate atypicalities in how individuals with ASD predict motion. The findings provide empirical support for the proposal of impaired prediction in ASD, and further suggest differential use of extra-retinal signals for motion prediction in ASD.

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35.18, 7:00 pm **Weaker neural suppression in autism spectrum disorder**

Michael-Paul Schallmo[1,2](schal110@umn.edu), Alex M Kale[2], Tamar Kolodny[2], Rachel Millin[2], Raphael A Bernier[3], Scott O Murray[2]; [1]Department of Psychiatry, University of Minnesota, [2]Department of Psychology, University of Washington, [3]Department of Psychiatry and Behavioral Science, University of Washington

Autism spectrum disorder (ASD) is often hypothesized to stem from a dysregulation of neural activity resulting in an imbalance of excitation and inhibition. While this is supported by specific animal models of ASD, there is little direct experimental support for this hypothesis from human studies. Using a visual paradigm, we tested whether mechanisms that regulate neural activity may be disrupted in individuals with ASD. Specifically, within the visual system, a powerful suppressive regulatory effect occurs in neurons when a stimulus is presented that is larger than the neuron's classical receptive field – information from the surround suppresses the neural response to the stimulus in the center. We used a well-known psychophysical paradigm that reflects this spatial suppression by measuring the amount of time required to perceive the motion direction of stimuli at various sizes. In addition, we used fMRI to measure neural suppression in the motion sensitive region called human MT complex (hMT+). In both the psychophysical and fMRI measurements, we found strong evidence of reduced suppression in individuals with ASD compared to neurotypical controls. We further tested the mechanism of impaired suppression by measuring GABA levels in hMT+ using MR spectroscopy, and observed no difference in GABA levels between ASD and control groups. Our results suggest that differences in suppressive regulatory mechanisms in ASD may result from altered neural responses, but not from a specific difference in GABA levels.

Acknowledgement: R01 MH106520

Object Recognition: Categories

Sunday, May 20, 5:15 - 7:15 pm, Talk Room 2

Moderator: Wilson Geisler

35.21, 5:15 pm **Understanding camouflage detection**

Abhranil Das[1](abhranil@abhranil.net), Wilson S Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin

Occurrences of camouflage in nature evoke fascination and wonder in us. Less appreciated are the forces that shaped their evolution: the visual systems of their predators and prey. Indeed, having been filtered by them, camouflage specimens — no matter how ingenious — are poised near the edge of detectability, their inventiveness only testifying to the sophistication of the detection machinery that pruned even slightly less

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crafty variants. Using theory, computation and experiment, we have begun to investigate the mechanisms involved in detecting camouflage in nature. In particular, we consider the scenario where the camouflaging animal has exactly mimicked the background texture. In this case, the visual information usable for detection lies only at the boundary between the animal and background. We begin therefore by defining a measure of boundary mismatch: a computational measure of image discontinuities at the boundary that putatively summarizes most of this available information. We then synthesize artificial stimuli using 1/f noise as the camouflage texture (this shares the same spatial frequency properties as natural images, but lacks further structure), and assess human performance in a series of target-detection experiments. We find regular variation in the detectability of these stimuli as a function of boundary mismatch, allowing us to measure boundary-mismatch thresholds as a function of task-relevant stimulus dimensions like luminance, contrast and duration. We plan to extend this analysis to variations in the size, distance and shape of the target, and with naturalistic texture stimuli (e.g., see Portilla and Simoncelli, 2000). These ideas can also be brought to the question of engineering effective camouflage. The boundary-mismatch measure allows us to compute the best location on a background to hide against, and compare the effectiveness of different textures towards this goal. These computational results can be connected to actual detectability using the results of our psychophysical experiments.

Acknowledgement: NIH grant EY11747

35.22, 5:30 pm **Interdigitation of words and faces in the ventral visual stream: reevaluating the spatial organization of category selective cortex using intracranial EEG** Matthew J Boring[1,2](mjb200@pitt.edu), Edward H Silson[3], Yuanning Li[2], Michael J Ward[4], Chris I Baker[3], Mark R Richardson[2,4], Avniel S Ghuman[1,2,4]; [1]Center for Neuroscience, University of Pittsburgh, [2]Center for the Neural Basis of Cognition, Carnegie Mellon University and University of Pittsburgh , [3]National Institute of Mental Health, NIH, [4]Department of Neurological Surgery, University of Pittsburgh

The map of category-selective regions in the human ventral visual stream provides organizational constraints to visual recognition. While some principles of the organization have been established, such as medial-lateral differentiation by stimuli that vary in their typical retinotopic eccentricity, the relative position of word and face selective areas, both of which are foveated, remains unclear. Some studies suggest that face selective areas tend to be medial to word selective areas, though the response to these stimuli have infrequently been compared to one another within the same subjects. Here we present evidence that challenges this organization from invasive neural recordings from 30 patients with intractable epilepsy using a combination of multivariate decoding accuracy, broadband gamma response, and event related potential amplitude. In these patients we found strong category-specific responses in the ventral visual stream, with house and tool specific responses distributing more medially than faces and words, consistent with previous studies suggesting a medial-lateral organization by typical retinotopic eccentricity. However, we found no medial-lateral bias for words and face selective areas at a group level. In fact, in some individual subjects, word specificity was medial to face specificity, and in others strongly face and word specific patches alternated (e.g. patches alternated face-word-face or word-face-word in the lateral-medial direction). We compare these results with similar category mapping on participants with ultra-high-resolution 7 Tesla MRI to determine if similar interdigitation of word and face selective voxels exists when looking at a fine scale using fMRI. Our results suggest an organization of the ventral stream wherein word sensitive patches and face sensitive patches, two classes of visual objects that are foveated, are finely interdigitated with little-to-no medial-lateral biases relative to each other.

Acknowledgement: NIH T32NS007433-20 to MJB and NIH R01MH107797 to ASG

35.23, 5:45 pm **A preference for mathematical tasks outweighs the selectivity for Arabic numbers in the inferior temporal gyrus** Mareike Grotheer[1](grotheer@stanford.edu), Brianna Lynn Jeska[1], Kalanit Grill-Spector[1,2,3]; [1]Psychology Department, Stanford University, Stanford, CA 94305, USA., [2]Neurosciences Program, Stanford University School of Medicine, Stanford, CA 94305, USA., [3]Stanford Neurosciences Institute, Stanford University, Stanford, CA 94305, USA.

The ability to perform basic math is crucial for our daily life, yet how our brain supports this skill is not fully understood. Recent research has identified an area in the human inferior temporal gyrus (ITG), which responds more strongly to Arabic numbers relative to other visual stimuli and is hence suggested to be responsible for the visual encoding of numbers. However, other recent studies have reported activations in the ITG during mathematical tasks, even in the absence of visually presented numbers. To address this debate, we conducted three fMRI experiments in 15 participants that systematically varied tasks and visual stimuli. While we replicated findings of higher ITG responses to Arabic numbers than character-like stimuli during a 1-back task, this preference to Arabic numbers was abolished when participants were engaged in mathematical processing. Instead responses in the ITG were higher when subjects were engaged in adding vs. reading or color tasks, irrespective of the stimuli the tasks were performed on (number/letter morphs, hands, or dice). Likewise, multivariate pattern analyses reveal that mathematical task can be successfully and consistently decoded from distributed ITG responses (mean decoding accuracy across experiments (±SEM): 89(3)%). Decoding of task was also substantially higher than decoding of number stimulus, which was not robust (mean decoding accuracy across experiments (±SEM): 53(4)%). These data suggest that the ITG is involved in mathematical processing rather than the visual processing of Arabic number form. We propose that this region ascribes numerical content to visual inputs, irrespective of the nature of the stimulus.

Acknowledgement: This research was supported by the NIH (1R01EY02391501A1) and by the DFG (GR 4850/1-1).

35.24, 6:00 pm **The ventral visual pathway represents animal appearance rather than animacy, unlike human behavior and deep neural networks** Stefania Bracci[1](stefanie.bracci@gmail.com), Ioannis Kalfas[2], Hans Op de Beeck[1]; [1]Laboratory of Biological Psychology, KU Leuven, Leuven, 3000, Belgium, [2]Laboratory of Neuro- and Psychophysiology, Department of Neurosciences, KU Leuven, Leuven, 3000, Belgium

The ventral visual pathway contains rich representations of objects, with information about both their visual properties and category membership at multiple hierarchical levels, including animate versus inanimate. These neural representations show general agreement with behavioral similarity judgments and with representational similarities in "deep" convolutional neural networks. In this event-related functional neuroimaging study (n = 16), we challenge this state-of-the-art by dissociating object appearance (how does the object look like?) from object category (which object category is it?). The stimulus set includes animate objects (e.g., a cow), typical inanimate objects (e.g., a mug), and, crucially, inanimate objects that look like the animate objects (e.g., a cow-shaped mug). Behavioral judgments and deep neural networks showed a strong effect of the animacy dimension, setting the lookalike (and inanimate) objects apart from the animate ones. In contrast, neural activity patterns in ventral occipitotemporal regions were strongly biased towards object appearance: animate entities and lookalikes were similarly represented, and separated from the regular inanimate objects. Animacy, despite its importance for human behavior and neural networks, is not well represented in ventral visual cortex.

Acknowledgement: Research Foundation Flanders (FWO)

35.25, 6:15 pm **Endogenous oscillatory activity modulates category tuning in ventral temporal cortex** Yuanning Li[1,2,3](ynli@cmu.edu), Michael J Ward[2], Mark Richardson[2,3], Max G G'Sell[4], Avniel S Ghuman[2,3]; [1]Joint Program in Neural Computation and Machine Learning, Carnegie Mellon University, [2]Department of Neurological Surgery, School of Medicine, University of Pittsburgh, [3]Center for the Neural Basis of Cognition, Carnegie Mellon University and University of Pittsburgh, [4]Department of Statistics and Data Science, Carnegie Mellon University

Perception of sensory inputs is modulated by shifts in endogenous, ongoing brain states. Specifically, previous studies have tied endogenous states measured by the pre-stimulus neural activity to behavior in visual tasks. However, it remains unclear whether the endogenous shifts modulate neural coding and category tuning in the ventral stream, which could provide a neural pathway for behavioral modulation. To address these questions, we collected intracranial electroencephalography (iEEG) data from a large cohort of 32 patients while viewing visual images. We analyzed the iEEG data recorded from 230 channels showing category-selectivity for 5 different categories of visual stimuli: faces, human bodies, words, places, and tools. A generalized linear model was trained to classify the category of the stimuli, and the trained model was used to extract the linear subspace that maximized the category-selectivity in post-stimulus neural activity. We used the projection of neural activity in this linear subspace as the neural metric of category-selectivity of single trials, and evaluated the dependency between the pre-stimulus oscillatory activity and the post-stimulus category-selective activity. We found that the pre-stimulus oscillatory activity predicted the magnitude of the post-stimulus category selectivity on a single-trial basis. Specifically, different patterns of pre-stimulus activity led to different degrees of category tuning in the category-selective areas. These results demonstrate that endogenous activity modulates category tuning in ventral temporal cortex, providing a potential neural basis for perceptual modulation by endogenous activity.

Acknowledgement: NIH R90DA023420 NIH R01MH107797 NIH R21MH103592 NSF 1734907

35.26, 6:30 pm **The balanced act of crossmodal and intramodal plasticity: Enhanced representation of auditory categories in the occipital cortex of early blind people links to reduced temporal coding** Stefania Mattioni[1,2](stefania.mattioni@unitn.it), Mohamed Rezk[2], Ceren Battal[1,2], Jyothirmayi Vadlamudi[2], Olivier Collignon[1,2]; [1]Center for Mind/Brain Sciences (CIMEC), University of Trento, Italy, [2]Institute of Psychology (IPSY) and Institute of Neuroscience (IONS), University of Louvain-la-Neuve, Belgium

Early visual deprivation triggers enhanced representation of auditory information in the occipital cortex. How does this crossmodal plasticity mechanism impact on the temporal cortex that typically involves in similar auditory coding? To address this question, we used fMRI to characterize brain responses of early blind (EB) and sighted control (SC) individuals listening to sounds from four different categories (human, animal, objects and places). Multivariate pattern analysis was used to decode these four classes of stimuli into individually defined occipital and temporal anatomical parcels. We observed opposite effects of early visual deprivation on auditory decoding in occipital and temporal regions. While occipital regions contained more information about sound categories in the blind, the temporal cortex showed higher decoding in the sighted. Moreover, we observed a negative correlation between occipital and temporal decoding of sound categories in EB, suggesting that these intramodal and crossmodal reorganizations might be inter-connected. Interestingly, we also found that this reorganization process mostly arises in the right hemisphere, which is also the most recruited during the task. We therefore suggest that the extension of non-visual functions in the occipital cortex of EB triggers a network-level reorganization that may reduce the computational load of the regions typically coding for the remaining senses.

Acknowledgement: European Research Council starting grant (MADVIS grant #337573)

35.27, 6:45 pm **Curved features are critical for animate/inanimate categorization in macaques** Marissa A Yetter[1](yetterma@nih.gov), Mark Eldridge[2], Grace Mammarella[2], Leslie G Ungerleider[1], Xiaomin Yue[1]; [1]Laboratory of Brain and Cognition, NIMH, NIH, [2]Laboratory of Neuropsychology, NIMH, NIH

In an earlier fMRI study, we showed that multivoxel activity patterns, measured with support vector machine classification, encoded animate vs. inanimate categories in the macaque inferior temporal cortex. However, the classification accuracy was reduced to chance after removing the variance in the fMRI activity patterns that was explained by the curved and rectilinear image features, as quantified using curved and rectilinear Gabor filters. These results indicate that categorization in the macaque inferior temporal cortex might not stem from acquired semantic knowledge of the characteristics that distinguish animate from inanimate object categories, but rather from the unique image-based features. The current experiment was designed to directly examine those two possibilities using behavioral tests. First, one rhesus macaque was trained to categorize images of animate and inanimate objects. Then, the same monkey was tested on a large number of trial-unique images of animate and inanimate objects across five days to assess whether this training generalized to unfamiliar objects. We found that the animal's classification accuracy for these unfamiliar objects averaged 84.55%, supporting our fMRI conclusion that animate/inanimate categorization does not stem from acquired semantic knowledge of animate vs. inanimate categories. We also tested whether image features that differ substantially between the two object categories, such as curvilinear and rectilinear information, contribute to the monkey's classification accuracy. The same animal was tested across five days on sets of synthetic animate and inanimate images created using an algorithm that significantly distorted the global shape of the original images, while maintaining the original images' intermediate features (e.g. curvilinear and rectilinear information). We found that the animal's classification accuracy was significantly above chance (63.57%), suggesting that unique image-based features, such as curvilinear features, distinguish animate from inanimate objects and give rise to the formation of animate/inanimate categorization in macaques to some extent.

35.28, 7:00 pm **One shot learning of novel object classes** Yaniv Morgenstern[1](yaniv.morgenstern@psychol.uni-giessen.de), Filipp Schmidt[1], Roland W Fleming[1]; [1]Justus-Liebig-University Giessen

One of our most remarkable visual abilities is the capacity to learn novel object classes from very little data. Given just a single novel object, we usually have certain intuitions about what other class members are likely to look like. Such 'one-shot learning' presumably leverages knowledge from previously learned objects, particularly: (1) by providing a feature space for representing shapes and their relationships and (2) by learning how classes are typically distributed in this space. To test this, we synthesized 20 shape classes based on unique unfamiliar 2D base shapes. Novel exemplars were created by transforming the base shape's skeletal representation to produce new shapes with limbs varying in length, width, position, and orientation. Using crowdsourcing, we then obtained responses from 500 human observers on 20 trials (1 response for each base shape). On each trial, observers judged whether a target shape was in the same class as 1 or 16 context shape(s) (transformed samples with similar characteristics). Targets came from the same class as the context shape(s), but differed in their similarity. The results reveal that participants only perceive objects to belong to the same class when they differed from one another by a limited amount, confirming that observers have restricted generalization gradients around completely novel stimuli. We then compared human responses to a computational model in which the similarity between target and context shapes was computed from >100 image-computable shape descriptors (e.g., area, compactness, shape context, Fourier descriptors). The findings reveal a surprisingly consistent distance around each base shape in the feature space, beyond which objects are deemed to belong to different classes. Thus, the model predicts one-shot learning surprisingly well with only one free parameter describing how different objects in the same class tend to be from one another.

Acknowledgement: DFG (SFB-TRR-135) and ERC(ERC-2015-CoG-682859)

Sunday Afternoon Posters

Faces: Learning, development, aging

Sunday, May 20, 2:45 - 6:45 pm, Banyan Breezeway

36.301 **Building a representation of newly encountered faces: A role for context?** Kristen A Baker[1](kb09gi@brocku.ca), Catherine J Mondloch[1]; [1]Brock University

Recognizing identity in naturalistic images of unfamiliar faces is challenging (Jenkins et al., 2011); two images of the same person often are misperceived as belonging to different people and images of different people often are misperceived as belonging to the same person. Thus, face learning involves increased tolerance of within-person variability in appearance and improved discrimination. We examined the process by which a perceiver determines the range of inputs that are attributable to a newly learned identity, such that novel images of that identity are recognized while those of a similar identity are excluded. Based on Tanaka's (2007) hypothesis that each identity is represented by an attractor field in multi-dimensional face space, the size of which is constrained by nearest neighbors, we predicted that learning a new face in the context of a similar identity would facilitate learning. In Experiment 1, participants (n=40) sorted 45 ambient images of three identities (15/identity) in the learning phase; two identities were similar (near neighbours) and one was dissimilar (far neighbour). In the test phase, participants identified new images of the learned identities when intermixed with novel identities. Performance (d', hits, FAs) did not vary for near vs. far neighbours, ps>0.15—perhaps because accuracy approached ceiling. In Experiment 2, participants (to date, n=24) sorted only 15 images to capture the representation of identity earlier in the learning process. Performance was worse in Experiment 2, p< 0.001; participants made fewer hits and more false alarms. Nonetheless, performance did not vary for near vs. far neighbours, ps>0.21. Collectively our findings confirm that identity learning involves both improved recognition of new instances (increased tolerance of variability) and improved discrimination. To date, though, we find no evidence that this learning is best accounted for by Valentine's (1991) multi-dimensional face space model, calling for revised theories of face recognition.

Acknowledgement: NSERC

36.302 **The effect of practice with inverted faces on behavioural and ERP horizontal bias.** Ali Hashemi[1](hashea@mcmaster.ca), Matthew V Pachai[2], Patrick J Bennett[1], Allison B Sekuler[1,3,4]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Brain Mind Institute, School of Life Sciences, École Polytechnique Fédérale de Lausanne, [3]Rotman Research Institute, Baycrest Health Sciences, [4]Department of Psychology, University of Toronto

Face identification relies on the use of horizontally-oriented facial structure. The degree of horizontal bias (HB) is correlated with overall face identification accuracy, as well as the size of the inversion effect, and HB to inverted faces increases after practice with identifying inverted faces. In addition, faces elicit an EEG response sensitive to horizontal structure: When the horizontal structure of upright faces is removed, the N170 is delayed and reduced in amplitude, and the N250 also is reduced in amplitude. Furthermore, the N250 amplitude difference to horizontal vs. vertical structure is correlated with upright face identification accuracy. Here, we asked if the sensitivity of the N170 and N250 to horizontal structure in inverted faces changes with practice. Eleven participants completed a one-of-six inverted face identification task. Over the course of 2 sessions, identification accuracy improved from 56% to 78% (compared to >90% accuracy for upright versions of the stimuli). Before and after training, we measured identification accuracy and ERPs to vertically or horizontally filtered faces of varying filter bandwidths. Response accuracy improved most when horizontal structure was visible, and post-training HB correlated with unfiltered face identification accuracy. N170 amplitude, but not N250 amplitude, decreased when horizontal structure was removed, but these effects of orientation were not influenced by training. Neither N170 or N250 amplitude HB were correlated with unfiltered, inverted face identification accuracy. N170 latency increased with the removal of vertical or horizontal structure, but the difference between orientations was not significant before or after training. Nonetheless, post-training N170 latency HB was correlated with unfiltered face identification accuracy. Overall, our results indicate that although a relatively short amount of practice with inverted faces improves behavioural performance and HB, such training does not differentially alter the sensitivity of the N170 or N250 to horizontal and vertical facial structure.

Acknowledgement: NSERC

36.303 **Does categorization training change the encoding of face identity?** Fabian A Soto[1](fabian.soto@fiu.edu); [1]Department of Psychology, Florida International University

Previous research suggests that learning to categorize faces along a novel identity dimension (created by morphing between two unfamiliar faces) changes the perceptual representation of the category-relevant dimension, increasing its discriminability, its separability from other dimensions, and the information used to identify faces varying along the dimension. An open question is whether categorization training modifies the encoding of face identities at the extremes of the category-relevant dimension (i.e., the parent faces used to create such dimension). This encoding has been proposed to be norm-based, a hypothesis supported by studies showing that recognition of a face identity is facilitated by adaptation to an "anti-face". Here, we trained a group of participants to categorize faces that varied along two morphing dimensions, one of them relevant to the categorization task and the other irrelevant to the task. A control group did not receive such categorization training. During test, thresholds for the identification of one of the extremes of the category-relevant dimension were obtained using the method of constant stimuli, with stimuli varying from an average face to the target identity. For each participant, thresholds were obtained in three conditions: no adaptor, anti-face adaptation, and category adaptation (exposure to the other extreme in the category-relevant dimension). Surprisingly, categorization training had very little effect on identification thresholds in the absence of an adaptor, suggesting that increments in discriminability commonly found after categorization are specific to the trained morphed dimension, and do not transfer to a task involving detection of a single dimension extreme. Secondly, anti-face adaptation produced a reduction in thresholds that was comparable in both groups, suggesting that categorization training does not influence the norm-based encoding of face identity. Finally, category adaptation produced a reduction in thresholds that was slightly stronger after categorization training.

36.304 **Effectiveness of a Facial Forensic Training Course** P Jonathon Phillips[1](jonathon@nist.gov), Rebecca Heyer[2], Dana Michalski[2]; [1]National Institute of Standards and Technology, [2]Defence Science and Technology Group

Forensic facial examiners are professionals trained to identify faces in images. They have extensive training, and their identity comparisons involve a rigorous process. Part of their training includes completion of courses that teach them methods for identifying faces. The goal of this study was to determine if a course improved the face matching accuracy of the students. The course was 10 days in length and took place over two consecutive business weeks. Ten students in the class volunteered to participate in the study. To be able to compare face matching ability with published results in the literature, the Glasgow Face Matching Test was administered on the morning of the first day of class. To measure the change in face matching ability over the course, two tests of equal difficulty were created. The image-pairs in the two tests (n1=30 and n2=29) were from White et al 2015 Proceedings of the Royal Society. Accuracy for each subject was measured by area under the ROC (AUC). Results: Half of the students' accuracies increased between the first and second tests; the other decreased. The accuracies of all the students were comparable to the super-recognizers in Robertson et al, 2016, PLoS One; the students were comparable to the forensic facial examiners in White et al 2015. Conclusions: The test results did not show an increase in performance

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over the course. The students already had superior face matching ability. The distributions of students' AUCs on the before and after tests were comparable; however, there was a high within subject variability. Recommendations: Future tests are designed for students with superior face matching ability. The tests allow students sufficient time to use the tools and methods taught in the class. The within subject variability on face matching and recognition tasks needs to be quantified.

36.305 **Does face-drawing experience enhance face processing abilities? Evidence from hidden Markov modeling of eye movements** Janet H. Hsiao[1](jhsiao@hku.hk), Hui Fei Chan[1], Tze Kwan Li[1], Antoni B. Chan[2]; [1]Department of Psychology, University of Hong Kong, [2]Department of Computer Science, City University of Hong Kong

Recent research has suggested the importance of part-based information in face recognition in addition to global information. Consistent with this finding, eye movement patterns that focus on individual eyes in addition to the face center (analytic patterns) were associated with better recognition performance (Chuk et al., 2017). Nevertheless, face drawing experience was reported to enhance selective attention to face parts but not face recognition performance (Zhou et al., 2012; Tree et al., 2017), presenting a counter example. Here we examined whether eye movement patterns and performances in simultaneous face matching, face recognition (old/new judgment), and part-whole effect (whole face advantage) were modulated by face drawing experience through the Eye Movement analysis with Hidden Markov Models (EMHMM) approach. This approach summarizes an individual's eye movements in terms of personalized regions of interest (ROIs) and transition probabilities among the ROIs using a hidden Markov model (HMM), and similarities among individual HMMs can be quantitatively assessed through log-likelihood measures. We recruited 39 face artists and 39 matched novices. Through clustering participants' eye movement HMMs, we discovered analytic (focusing more on the eyes) and holistic patterns (focusing more on the face center) in all three tasks. Face artists adopted patterns that were more analytic and had better performance than novices in face matching, and participants' drawing ratings were correlated with both eye movement similarity to analytic patterns and face matching performance. In contrast, although in general analytic patterns were associated with better face recognition performance and increased part advantage, artists and novices did not differ in eye movements, recognition performance, or part-whole effect. These results confirm the importance of retrieving part-based information in addition to global information through analytic eye movement patterns in face processing, and suggest that face artists' advantage in face processing is limited to perceptual judgments similar to their drawing experience.

Acknowledgement: Research Grant Council of Hong Kong (GRF #17402814)

36.306 **Greeble Training in Adolescents Increases Neural Activation in the FFA** Giorgia Picci[1](gup129@psu.edu), Marlene Behrmann[2], Suzanne Scherf[1]; [1]Psychology, College of Liberal Arts, The Pennsylvania State University, [2]Psychology, Dietrich College of Humanities and Social Sciences, Carnegie Mellon University

People with autism have difficulties perceiving faces, including recognizing individual faces. Also, neural activation in the right fusiform gyrus in response to faces is reportedly hypoactive. One mechanistic hypothesis for these deficits is that people with autism have difficulty engaging holistic processing that is supported by the right fusiform face area (FFA). The central goal of this study was to determine whether individuals with autism can learn to recognize perceptually homogeneous novel objects (Greebles) using holistic processing and whether they engage the right FFA when so doing. Adolescents with autism were trained to recognize Greebles in a home-based computer-training paradigm for 2 months. Holistic processing of Greebles and neural activation during Greeble and face recognition was measured prior to and following the training using fMRI. Responses were compared to age- and IQ-matched typically developing (TD) adolescents who did not undergo the training and were only assessed at one time point. The adolescents with autism learned to recognize the Greebles using holistic processing. Furthermore, during Greeble recognition, they exhibited increased activation following the training in the right FFA, but not in the LOC, an object-selective cortical region. The Greeble-elicited FFA activation following the training was higher than that exhibited by the TD adolescents, who did not exhibit holistic processing of Greebles. There were no neural changes in these same regions in response to human faces in the autism group. These findings reveal that adolescents with autism can engage holistic processing during object recognition and that the right FFA may be recruited to do so. The implication is that the difficulty with face processing is not related to general atypicalities in visual processing or the functioning of the fusiform gyrus, but are, instead, related to more specific differences in visual processing and neural responsiveness to faces.

Acknowledgement: Pennsylvania Department of Health

36.307 **Neural sensitivity to face animacy in childhood** Benjamin Balas[1](benjamin.balas@ndsu.edu), Laurie Bayet[2], Alyson Saville[1]; [1]North Dakota State University, [2]Children's Hospital Boston

Adult observers are sensitive to the difference between real and artificial face appearance. Real faces are distinguished from artificial faces easily, and relative to real faces, artificial faces are remembered more poorly (Balas & Pacella, 2015) and trustworthiness is perceived less accurately (Balas & Pacella, 2017). These results, among others, suggest that artificial faces represent an "out-group" of faces, like other-race or other-age faces, based on the extent to which they deviate from faces that dominate experience. How does this sensitivity to artificial appearance develop? Other-race and other-age effects are malleable during childhood, which suggests that children's sensitivity to artificial faces could differ from that of adults. Presently, we chose to examine this question using neural responses (e.g. the N170 ERP component) to real vs. artificial face appearance as a means of characterizing face processing in school-age children. We recruited a total of 36 children between the ages of 5-10 years old (18 5-7 years old, 18 8-10 years old) to participate in this study. We recorded ERPs from each participant while they viewed randomly presented images of upright and inverted faces that either depicted real people or dolls. Specifically, we examined the sensitivity of the P100 and the N170 to real vs. artificial appearance and face orientation. We found that unlike adults (Balas, van Laamswerde & Saville, 2017), the mean amplitude of the N170 did differ as a function of both orientation $F(1,34) = 8.45$, $p = 0.006$) and face animacy ($F(1,34) = 10.98$, $p = 0.002$). Thus, while we usually think of face processing becoming more fine-tuned with continuing development, these results suggest that children have more sensitivity to the real/artificial distinction at early ERP components than adult observers do. Face animacy may be a unique case where some stages of face processing encode category differences more weakly as development proceeds.

Acknowledgement: NSF 1348627

36.308 **Categorization of face race and sex in preschool-aged children by means of fast periodic visual stimulation.** Ryan A Barry-Anwar[1](rbarryanwar@ufl.edu), Stefania Conte[2], Lisa S Scott[1]; [1]Department of Psychology, University of Florida, [2]Department of Psychology, University of Milano-Bicocca

Preschool-aged children have been found to show superior recognition of own-race faces (Sangrigoli & de Schonen, 2004). However, the developmental trajectory of the categorization of face sex and face race during the preschool years is not well understood. Here 4-year-old and 5-year-old neural categorization of sex and race was examined using fast periodic visual stimulation. Continuous EEG was recorded in a group of Caucasian 4- (n=6) and 5-year old children (n= 6) while faces from one category were presented at a frequency of 6 Hz (the standard category). Every 5th face was a face from a different category (the oddball category presented at 1.2 Hz). We tested for 4 types of categorization: 1) race categorization within male faces, 2) race categorization within female faces, 3) sex categorization within familiar race faces, and 4) sex categorization within unfamiliar race faces. It was predicted that children would show robust evidence of neural categorization within the most commonly experienced groups (female faces and familiar race faces). Preliminary results show a significant standard visual response (6 Hz) for all 4 conditions (p's < .001; Figure 1). Separate analyses of the categorization of face sex and face race were conducted for the 1.2 Hz response across ages (4 years, 5 years) and regions (left occipitotemporal, left occipital, occipital, right occipital, right occipitotemporal). Both ages categorized sex over posterior scalp regions ($p < .05$; Figure 2). When categorizing faces by race, 5-year-old children's 1.2 Hz response was more right lateralized than 4-year-olds (p's < .05). The present results suggest age differences when preschool aged children perceptually categorize faces by race but not by sex. The perceptual

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categorization differences, reported here, for face race are consistent with behavioral studies examining race biases in 5 year olds (Kinzler et al., 2009; Shutts et al., 2013).

36.309 **Seeing morphing faces of own- and other-race: the development of face discrimination in 3- to 7-year-old Taiwanese children** Sarina Hui-Lin Chien[1,2](sarinachien@mail.cmu.edu.tw), Shu-Fei Yang[1], En-Yun Hsiung[2], Chun-Man Chen[2]; [1]Graduate Institute of Neural & Cognitive Sciences, College of Medicine, China Medical University, [2]Graduate Institute of Biomedical Sciences, College of Medicine, China Medical University

Introduction. Previous studies on the other-race effect (ORE) in preschoolers and children mostly focused on recognition memory performance; however, the onset of ORE has been inconclusive across studies. Here we wish to explore the development of the ORE in 3- to 7-year-old Taiwanese children with a simultaneous morphing face discrimination task. Method. A set of morphed images of Caucasian and Asian male and female faces were used. In Experiment 1, 3- to 4-year-old children (N = 41) were tested with a forced-choice simultaneous pointing task. They viewed an Asian or Caucasian target parent face followed by a pair of comparison faces, with one being the "same parent" face and the other as a "different" morphed face (i.e., 30%, 60%, or 90% contribution from the other parent face). Children were asked to point out the same face with their fingers. In Experiment 2, 5- to 7-year-old children (N = 45) and adults (N=16) were tested with a forced-choice simultaneous matching task. The stimuli were the same as in Exp. 1, but the participants were asked to identify the face that was different from the target with keypress. Results. The results showed that, for all age groups, the accuracies of correctly pointing to the same or identifying the different face increased as the morph level increased, and the mean accuracies for the Asian- and Caucasian-parent conditions were about equal. Adults and 5- to 7-year-old children outperformed 3- and 4-year-old children at all morph levels; the performance of 7 year-olds at the three morph levels started to look adult-like. Conclusion. In sum, using the simultaneous morphing face pointing/matching task, the present study did not reveal an ORE in Taiwanese children aged between 3 and 7. However, a clear developmental progression in processing morphing faces was evident between young children and adults.

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36.310 **Recognition of approaching walkers in infancy** Megumi Kobayashi[1](megumik@inst-hsc.jp), So Kanazawa[2], Masami K Yamaguchi[3], Alice J O'Toole[4]; [1]Department of Functioning Science, Institute for Developmental Research, Aichi Human Service Center, [2]Department of Psychology, Japan Women's University, [3]Department of Psychology, Chuo University, [4]School of Behavioral and Brain Sciences, The University of Texas at Dallas

In natural viewing environments, we sometimes have to recognize people at a distance; for example, when someone approaches. In such cases, human adults utilize information from both face and body for person recognition (e.g., O'Toole et al., 2011, Hahn et al., 2016). We achieve person recognition by a significant ability to generalize our representation of the face and body of a person across different visual environments. In the developmental literature, previous studies have considered infants' face recognition from birth. These studies reported that infants' face recognition is invariant to rigid or non-rigid facial changes at around 7 months of age (e.g., Fagan et al., 1976), suggesting that infants have some generalizability of face recognition across facial transformations. However, no studies have explored infants' generalizability of face recognition across different natural-viewing environments. Therefore, we studied this ability by examining infants' recognition for the face of an approaching person after learning a face of person talking. To this end, we used a familiarization/novelty-preference procedure with 5- to 7-month-olds. In Experiment 1, infants learned a face with a video of a person talking. Recognition was tested with videos of person approaching from a distance. We found that only 7-month-olds could recognize the face of approaching person. Additionally, we confirmed that this recognition memory in 7-month-olds was based on the face, eliminating low-level visual cues in Experiments 2 and 3. When infants learned a face from a talking video and were tested with a talking video, 5- and 6-month-olds recognized the familiarized face in addition to the 7-month-olds (Experiment 4). In sum, we show that the ability to recognize the face of approaching person develops at 7 months of age. Our results suggest that 7-month-old infants can generalize their face recognition memory across the natural-viewing environments, whereas this ability is limited in younger infants.

36.311 **The development of emotion perception strategies in children.** Victoria Foglia[1](fogliav@mcmaster.ca), Haichao Zhang [1], Jennifer A. Walsh[1], M.D. Rutherford[1]; [1]Psychology, Neuroscience, and Behaviour, McMaster University

Introduction. Typically developing adults use a template-matching strategy when perceiving emotional facial expressions (Skinner & Benton, 2010). Tolerance of expression exaggeration allows a test of template matching: an extremely exaggerated expression would no longer match the stored template, but would still agree with a rule-based emotion perception strategy (Rutherford & McIntosh, 2007; Walsh, Vida, and Rutherford, 2014). The current study examines the emotion perception strategies of children between 6 and 15 years, to examine when the template matching strategy develops. Methods. Participants completed two tasks. In the Emotion task participants viewed pairs of happy or sad faces, blocked by emotion, with varying levels of exaggeration. They were asked to select the face that looked closest to how a happy (or sad) person would really look in real life. In the Realism task, participants saw the same stimuli but were asked to pick the most realistic face. Results. Using proportion of trials on which the more exaggerated face was chosen as the dependent variable, performance differed across age groups for the Emotions task but not the Realism task. A Mann-Whitney revealed that the youngest age group was more likely to select the exaggerated faces (Mdn=0.85) compared to the oldest age group (Mdn=0.125), U = 22.50, p = 0.024. There were no significant differences for the Realism task, $\chi^2(2) = 1.28$, p = 0.527. Similiarly, for the Emotions Task, results revealed a significant negative correlation between age and proportion of exaggerated faces selected, (r = -0.350, n = 34, p =.042). Tolerance for exaggerated faces decreases with age in the emotion perception task. This correlation was not significant for the Realism task (r = -.141, n = 34, p = .427). These results suggest that the use of a template-based strategy increases between 6 and 15 years of age.

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36.312 **Impact of Expressive Intensity on Age Differences in Fear and Anger Detection in the Periphery** Andrew Mienaltowski[1](andrew.mienaltowski@wku.edu), Brittany Groh[1], Dixi Secula[1], Allison Rinne[1], Connor Rogers[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University

Age differences in emotion recognition are moderated by the salience of the emotion cues available on facial stimuli. Salience can be influenced by the discrete emotion expressed, the intensity of expression, and the location of the social target relative to the observer. The current study examined how expressive intensity influenced younger and older adults' ability to detect fear and anger in face stimuli presented in the observer's peripheral field of view. Younger (n = 39, ages 18-26) and older (n = 40, ages 62-79) adults observed either fearful and neutral or angry and neutral expressions presented at 5, 10, and 15 degrees from a centrally presented fixation point in the left and right visual field. Generally, emotion detection performance declined when stimuli were presented at greater distances into the periphery. For fearful expressions, both age groups displayed better performance for high than for low expressive intensity stimuli. Older adults, however, displayed larger emotion detection deficits than did younger adults for low intensity relative to high intensity expressions despite having longer stimulus durations. For angry expressions, both age groups displayed worse performance for stimuli presented further from the center of the display and for stimuli that were low in expressive intensity. The differential age effects observed in the current study across emotion can be accounted for by age differences in the regions of the face utilized for decoding emotion. Older adults may focus less on eye-related emotion cues than younger adults when evaluating emotion on peripherally presented facial stimuli if the cues are subtle.

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36.313 **Age Differences in Emotional Enhancement of Visually-Evoked Early Posterior Negativity during Peripheral Emotion Detection**

Shelby A King[1](shelby.king7@gmail.com), Dixi S Secula [1], Allison Rinne[1], Alyssa Minton[1], Ashley Gilliam[1], Andrew Mienaltowski[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University

Advancing age is associated with declines in useful field of view and sensitivity to low spatial frequency information, both of which are important to detecting emotion in peripherally-presented faces. Age differences in emotion detection ability were explored by manipulating the expressive intensity of happy and angry faces and their peripheral location on a display. Younger (n = 27, ages 18-27) and older (n = 28, ages 60-79) adults observed emotional and neutral faces, blocked by emotion and intensity, at three different peripheral locations (5, 10, and 15 degrees) to the left and right of a central fixation point. The task consisted of 960 trials (240 per emotion and intensity) randomly distributed in equal proportions across the six peripheral locations. In addition to measuring psychophysical emotion detection performance, visually-evoked potentials time-locked to the onset of the faces were recorded to investigate the impact of emotion type, intensity, and stimulus location on a perceptual early posterior negativity (EPN) from 160 to 300 ms and linked to emotion categorization. Younger adults consistently outperformed older adults on the psychophysical tasks, but both performed better for higher than for lower intensity stimuli and worse overall at more distant peripheral locations. Age differences emerged in the late EPN such that, although both age groups showed an enhanced late EPN to happy expressions, only younger adults displayed an enhanced late EPN to angry expressions. These findings support the existence of age-related emotion perception deficits, but also suggest that these deficits are smaller for happy expressions which may be more salient in the periphery. The findings also provide neurophysiological evidence for a positivity effect for older adults within perceptual processes.

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36.314 **Processing speed and fluid intelligence contribute towards decline in facial emotion recognition ability across the adult lifespan**

Jennifer J Murphy[1](jennifer.murphy@kcl.ac.uk), Hayley Geary[1], Edward Millgate[1], Caroline Catmur[1], Geoff Bird[1,2]; [1]King's College London, [2]Oxford University

A body of research suggests that advancing age is associated with decline in emotion recognition, though the factors that contribute towards this decline remain unclear. While previous research suggested that declining emotion recognition ability may be related to cognitive (fluid intelligence, processing speed) and affective (e.g., depression) factors, recent theories highlight a potential role for alexithymia (impaired ability to identify and describe one's own emotions), and interoception (the perception of the body's internal state). The present study therefore aimed to examine factors mediating age-related changes in emotion recognition ability in a group of 140 20-90 year olds, and, using an identity recognition control task, to determine whether these mediating factors are specific to emotion recognition or contribute to generalised difficulties with face processing. Results revealed that age-related changes in emotion recognition ability were accounted for by changes in processing speed and fluid intelligence, with some contribution of depressive traits, and that this was specific to emotion recognition; none of the examined factors contributed towards changes in identity recognition. Contrary to predictions, interoception and alexithymia did not contribute towards age-related changes in emotion recognition.

Acknowledgement: ESRC

36.315 **The Eyes Have It: Age Differences in Emotion Detection for Open and Closed Mouth Expressions**

Allison M Rinne[1](allison.rinne334@topper.wku.edu), Dixi Secula[1], Shelby King[1], Alyssa Minton[1], Miriam Chinkers[1], Hannah Heisler[1], Greta Glide[1], Andrew Mienaltowski[1]; [1]Department of Psychological Sciences, Ogden College of Science and Engineering, Western Kentucky University

Emotion detection is essential for everyday social interactions. However, advancing age is associated with a decline in emotion recognition performance. The current study extends past research by asking younger and older adults to detect emotion cues on face stimuli presented in peripheral regions of the visual field. Younger (n = 27, age M = 20.6, SD = 2.4) and older observers (n = 28, age M = 70.4, SD = 5.5) were presented with individual face stimuli at three locations (5, 10, and 15 degrees) in the left and right visual fields. Angry and happy expressions with open and closed mouths were morphed to manipulate expressive intensity. The task was blocked by the combination of emotion and intensity, and participants indicated if facial stimuli were neutral or emotional. Although younger adults generally outperformed older adults, emotion detection accuracy was impacted in similar ways for each age group by expressive intensity, the mouth status of the image, and the distance from the central fixation point that the image appeared in the periphery. For angry faces, older adults struggled to detect emotion in low intensity, closed mouth stimuli, suggesting that older adults relied a great deal on mouth cues to inform their judgments. For happy faces, both age groups displayed proportionally more decline in emotion detection for closed mouth expressions at peripheral locations. Across emotion, the findings support an additive benefit of both high expressive intensity and an open mouth when decoding emotion from faces presented in the near periphery. Given that emotion expression in social interaction is more subtle, a general lack of this optimal state may challenge older observers, especially when social targets who are situated outside their central field of view are expressing negative emotion utilizing face regions other than the mouth.

Acknowledgement: National Science Foundation

36.316 **The effects of aging in neural processing of facial threat cues via magnocellular and parvocellular pathways.**

Hee Yeon Im[1,2](him3@mgh.harvard.edu), Reginald B Adams, Jr.[3], Cody A Cushing[1], Jasmine Boshyan[1,2], Noreen Ward[1], Kestutis Kveraga[1,2]; [1]Department of Radiology, Massachusetts General Hospital, [2]Harvard Medical School, [3]Department of Psychology, Pennsylvania State University

During face perception, we integrate facial expression and eye gaze to make social inferences from their combined signals. For example, a fearful face and averted eye gaze are both avoidance cues which indicate threat presence and its probable source, thus providing congruent, clear threat signal. Conversely, facial fear with direct gaze combines avoidance and approach cues, resulting in ambiguity about the threat source (Adams et al., 2012). We have shown (Im et al., 2017) that clear and ambiguous threat cues preferentially engage the magnocellular (M) and parvocellular (P) visual pathways, respectively. While aging is thought to degrade emotional perceptual abilities, its effects on threat cue processing in the M and P pathway processing are unknown. To fill this gap in knowledge, we scanned 108 participants ranging from 18 to 70 years old (65 females). We individually calibrated the luminance and color values of two-tone Mooney faces with direct or averted eye gaze to produce achromatic, < 8% luminance contrast (M) or isoluminant red/green (P) stimuli. The task was to identify the facial expression (neutral vs. fearful) as quickly and accurately as possible. Although older adults (OA, 41-70 years old) made slower responses than younger adults (YA, 18-40 years old), they remained as accurate as YA. In YA, we found greater left amygdala involvement in P-biased ambiguous threat cues and greater right amygdala involvement in M-biased clear threat cues. However, OA did not show such lateralized, pathway-specific attunement of the amygdalae. Furthermore, YA showed increased functional connectivity between the right amygdala and orbitofrontal cortex (OFC) for M-biased clear threat cues, and between the left amygdala and OFC for P-biased ambiguous threat cues. Together, our findings demonstrate that, compared to OA, YA showed greater pathway and hemispheric differentiation, and increased amygdala-OFC functional connectivity, while processing different types of compound threat cues.

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36.317 **The role of response inconsistency in older adults' face discrimination ability**

Sarah E. Creighton[1](creighs@mcmaster.ca), Patrick J. Bennett[1], Allison B. Sekuler[2,3,1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University, [2]Rotman Research Institute, Baycrest Health Sciences, [3]Department of Psychology, University of Toronto

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The efficiency with which observers discriminate faces declines with age. For example, using the classification image (CI) method with sub-sampled faces, Creighton et al (VSS 2014) showed that older adults sampled diagnostic face information less efficiently compared to younger adults. However, many older observers lacked obvious structure in their CIs, perhaps reflecting increased trial-to-trial variability in response strategy. Response consistency can be used to estimate the ratio of internal-to-external (i/e) noise affecting observers' decision. Here, we use the double-pass response consistency technique to estimate age-related changes in i/e ratios. Contrast thresholds were measured in 7 younger and 6 older observers performing a 2-AFC task for faces embedded in high external noise. In the first half of the experiment, noise fields were randomly generated on each trial, and stimulus contrast varied according to 2 interleaved staircases. In the second half of the experiment, this same sequence of face identities, contrast, and noise fields were repeated exactly, and percent correct and percent agreement (across the two halves) were calculated. The slope of the accuracy-vs.-consistency function was then used to estimate the magnitude of each observer's i/e ratio. To facilitate comparison with previous work (e.g., Gold et al, 2004; Creighton et al.), thresholds were measured with full and sub-sampled faces. Preliminary findings show higher thresholds in older than younger adults for both full- and sub-sampled faces, and this difference was greater for sub-sampled faces. The slopes of the consistency functions were slightly shallower for older than younger observers in the sub-sampled condition, suggesting increased thresholds partly reflect an age-related increase in older adults' i/e ratio. We currently are testing older observers from the original CI study to see if individual differences in response inconsistency are associated with the degree of structure observed in their CIs.

36.318 **Recognizing Faces Despite Variability in Appearance: Learning Mechanisms are Largely Intact in Older Adults** Claire M Matthews[1](cm10ph@brocku.ca), Harmonie S.J. Chan[1], Catherine J. Mondloch[1]; [1]Brock University

Recognition of unfamiliar faces is highly error-prone, especially across changes in appearance (e.g., hairstyle, expression, lighting). Despite a lifetime of experience perceiving faces, older adults demonstrate poorer performance than young adults on unfamiliar matching and face recognition tasks. However, past studies have used tightly controlled images and so examined image recognition, rather than face recognition per se. No study to date has examined older adults' ability to recognize unfamiliar faces despite natural variation in appearance or the process by which older adults become familiar with newly encountered identities. We tested older adults (n=57) on a battery of tasks. First, we verified that older adults were highly accurate at recognizing multiple images of a familiar face (95% on a familiar card sorting task). To investigate the efficiency with which older adults learn new faces, participants performed a recognition task after learning three new identities—one from a single image, one from a low variability video captured on a single day, and one from a high variability video filmed over three days. Unlike young adults (Baker et al., 2017), older adults only showed evidence of learning in the high-variability condition (p=.002). This is consistent with evidence that children need exposure to more variability than adults to new a face (Baker et al.). To investigate whether older adults' inefficient learning is attributable to deficits in underlying mechanisms, we examined their ability to use ensemble coding (to rapidly extract an average representation of an identity) and to benefit from viewing multiple images in a perceptual identity-matching task. The results from both of these tasks suggest that these mechanisms are intact; like young adults, older adults show evidence on ensemble coding (ps< .001) and benefitted from viewing multiple images of a new identity (p< .001). Taken together these results have implications for models of perceptual expertise.

Acknowledgement: NSERC

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Color and Light: Psychophysical and neural mechanisms

Sunday, May 20, 2:45 - 6:45 pm, Banyan Breezeway

36.319 **SSVEP amplitudes reflect hue selectivity in the human brain** Sae Kaneko[1,2](sakaneko@riec.tohoku.ac.jp), Ichiro Kuriki[1], Søren K Andersen[3]; [1]Research Institute of Electrical Communication, Tohoku University, [2]Japan Society for the Promotion of Science, [3]School of Psychology, The University of Aberdeen

The existence of neurons that selectively respond to the intermediate hues (hues off the cardinal axes of cone-opponent color space) in human early visual areas is still under debate. Kuriki et al. (2015) provided direct evidence for such neurons in human V1 to V4, using phase encoding mapping and a hue-selective adaptation paradigm in fMRI. Using similar stimuli as Kuriki et al. (2015), we now examine hue selectivity employing steady-state visual evoked potentials (SSVEPs). All colors used in this study were chosen from the equiluminant plane in the cone-opponent color space. The origin of this color space was Equal Energy White (EEW, 30 cd/m2): colors along the vertical axis only differ from the origin in S-cone response and those along the horizontal axis in L-cone (and incidentally in M-cone) response. Participants observed a 6 deg checkerboard pattern for 25 sec each trial. Half of the tiles (0.8 x 0.8 deg each) of the checkerboard were uniformly filled with the background hue (EEW), and the rest of them with the test hue. During the trial, the test hue smoothly changed at 24 s/cycle rate while the tiling pattern alternated at 5 Hz. To control participants' attentional state, they performed a simple Go/No-Go task at fixation. There were three color-contrast conditions; standard (full contrast, with ΔL = 8 %, ΔS = 80 %), half (4/40 %), and quarter (2/20 %). SSVEP amplitudes increased with color-contrast, suggesting that it reliably reflects hue-selective activity. Average SSVEP amplitude elicited by intermediate hues was just as large as to the cardinal hues and the circular profile of SSVEP amplitude along hue was neither point nor line symmetric, which supports Kuriki et al. (2015). We conclude that our approach using SSVEP is a valid technique to assess hue selectivity in the human brain.

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36.320 **Any double representation of the fovea? If there are ipsilateral connection from the eye to the LGN, why is there no cortical representation?** Mark M Schira[1](mark.schira@gmail.com); [1]School of Psychology, University of Wollongong, Australia

The debate about a double representation of the fovea in human visual cortex is still ongoing (Jordan et al. 2014). Ipsilateral connections from the retina to the LGN and hence visual cortex exist, they are reasonably well described (Stone 1973, Bunt & Minkler 1977, Fukuda et al. 1989) and some ipsilateral connections are found for the central 0.5 degrees in the fovea (1 degree in diameter). The retinotopic representation of the foveal confluence in human visual cortex, specifically the central 0.5 degree, is substantial with more that 2000 mm2 for V1, V2 and V3 alone (Schira et al. 2009). However, this area is representing the contralateral visual field, a representation of the ipsilateral visual field cannot be seen in the vicinity. It would have to be very small (less than 10mm2) to be undetectable. Reanalysing the data by Bunt & Minckler and Fukuda et al., only a very small count between 110 and 130 cells was estimated. When contemplating the impact for conscious perception three important facts need to be acknowledged: Firstly, while the ipsilateral overlap is relatively large in the periphery (up to 15 degree), close to the fovea it is smallest, either completely absent or less than 0.5 degree. Secondly, there are a substantial number of transcallosal fibers along the representation of the vertical meridian at the boundary of V1 and V2, especially in the foveal confluence (Zeki et al. 1969, Van Essen et al. 1986) suggesting a double representation would be superfluous. Finally, macular sparing, a popular argument for suggesting a substantial double representation, clearly cannot be well explained by an ipsilateral representation of the visual field. Quite obviously so, as many patients with hemianopia have no macular sparing whatsoever (Reinhard &Trauzettel-Klosinski, 2003), an observation that is irreconcilable with a significant ipsilateral representation.

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36.321 **Population receptive fields in V1 enlarge as luminance is reduced from photopic to scotopic levels** Antony B Morland[1,2](arm501@york.ac.uk), Barbar Molz[1], Rebecca Lowndes[1], Andre Gouws[1,2], Heidi Baseler[1,3]; [1]Department of Psychology, University of York, [2]York Neuroimaging Centre, University of York, [3]Hull-York Medical School, University of York

Under photopic conditions visual information is processed at the retinal level by cone photoreceptors while under scotopic light conditions visual signals are solely conveyed by rod photoreceptors. There is a markedly different distribution of rods and cones across the retina, most notably in the central fovea, where only cones are found. Spatial resolution is lower under scotopic compared to photopic conditions even at eccentricities at which there are greater rods than cones. This largely reflects the greater spatial summation in the rod compared to cone system. We sought to examine whether the increased spatial integration that is a feature of the rod pathway is reflected in changes in population receptive field characteristics in primary visual cortex. To this end we employed established population receptive field mapping techniques under four different luminances – two high light levels, 600 and 20 cdm-2, at which cones operate and two lower light levels 0.01 and 0.002 cdm-2, at which only rods operate. We then evaluated the population receptive field size in V1's representation of ~5-8deg eccentricity. This representation can be driven by either rods or cones. We found a strong effect of light level on population receptive field size, with the lower, scotopic light levels yielding larger estimates of size than those obtained at light levels that drive cones. However, there was no significant change in population receptive field size for the two of luminance levels used to drive cones or for the two used to drive rods. Our finding is in line with our hypothesis that neurons integrate information over larger areas of the visual field under scotopic compared to bright light conditions, highlighting the differences in spatial integration of the rod and cone pathways.

Acknowledgement: European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 641805, BBSRC

36.322 **Why are hV4 maps incomplete in the left visual cortex but complete in the right hemisphere?** Harriet G Boyd Taylor[1](ht380@uowmail.edu.au), Mark M Schira[1], Zoey J Isherwood[2], Alexander M Puckett[3]; [1]School of Psychology, University of Wollongong, Australia, [2]School of Psychology, University of New South Wales, Australia, [3]Queensland Brain Institute, University of Queensland, Australia

The hypothesis that surface draining veins distort measurements in human visual area V4 (hV4) offers an explanation for why retinotopic maps measured in this region often appear to contain only an incomplete hemifield (Winawer et al., 2010). Puckett et al. (2014) indicated that voxels contaminated by venous artefact display inverted responses to visual stimulation. Here, we aimed to quantify the relationship between venous eclipses and hV4 map coverage by assessing the proximity and behaviour of voxels in visual cortex contaminated by venous artefact. Subjects (N=11) viewed bowtie, ring, drifting bar and full field flash stimuli. A 0.75mm3 T1 anatomical image and 1.5mm3 functional EPIs were acquired over 1.5hrs. Visual areas were identified using pRF polar angle maps, correlation analyses were used to identify inverted voxels, and mean EPI luminance maps were used to identify venous eclipses. Cortical surfaces were generated using mrMesh and Caret 5 and functional analyses were conducted using mrVista. No consistent relationship was found between the presence or absence of a venous eclipse and incomplete maps of hV4. Furthermore, there was no statistically significant difference in the number of inverted voxels present across visual areas V1 to hV4. Mean maps 2.5mm above the grey/white boundary accurately reveal locations of larger veins, showing for the first time exactly where venous artefact would be expected to impact retinotopic maps. Venous eclipses appear in conjunction with incomplete maps of hV4, however cannot explain every instance. Complete maps of hV4 were sometimes present despite a strong venous eclipse in immediate proximity. It remains unclear whether venous artefact causes increased numbers of inverted voxels in hV4, however with more accurate images of the venous eclipse, it is possible that future analyses, including across several laminae, will further disambiguate problems affecting our ability to accurately map hV4.

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36.323 **Dynamics of contrast adaptation in central and peripheral vision** Yi Gao[1](yi.gao0525@outlook.com), Michael A. Webster[1], Fang Jiang[1]; [1]University of Nevada Reno

Visual adaptation can operate over multiple timescales to adjust sensitivity for different rates and durations of stimulus change. Adaptation has also been found to increase with eccentricity, yet how eccentricity affects the time course of visual adaptation remains largely unknown. In the current study, we examined these dynamics by tracking the time course of contrast adaptation in both the central visual field and periphery (at 10° eccentricity) using a yes/ no detection task to monitor contrast thresholds. Adapters were 1.5 cycle/degree Gabor patches with a diameter of 5°, counterphase flickering at 5Hz. Consistent with previous studies, aftereffects on 4° test stimuli were stronger in the periphery than in the center when adapting to equivalent high contrast (90%) patterns. Peripheral adaptation remained stronger even when contrast was reduced to one-third (30%) the foveal contrast. The time course of the threshold changes was fitted with separate exponential functions to estimate the time constants during the adaptation and post-adapt phases. Compared to the central adaptation, adaptation effects built up and decayed more slowly in the periphery, and surprisingly did not decay completely to the baseline within the monitored post-adapt period (400 s). Similar results were replicated with the tilt aftereffect using a 2AFC orientation discrimination task. Across all the experiments, there was no correlation between maximum adaptation strength and halftime of the decay phase, suggesting that the slower decay rate in the periphery was not due to a larger adaptation magnitude. Our results indicate that the dynamics of contrast adaptation differs qualitatively between central and peripheral vision, with the periphery adapting not only more strongly but also more slowly. EY023268 to Fang Jiang, EY10834 to Michael A. Webster

Acknowledgement: EY023268 to Fang Jiang, EY10834 to Michael A. Webster

36.324 **Examining the effect of context on the watercolor illusion** Ralph G Hale[1](rusty7@uga.edu), James M Brown[1]; [1]Department of Psychology, University of Georgia

The watercolor illusion (WCI) occurs when a physically non-colored region surrounded by an outer contour and an inner fringe of contrasting hue appears filled in with a pale tint the same hue as the fringe. Previous WCI research has focused primarily on stimulus parameters affecting illusion magnitude and the likely neural mechanisms responsible, rarely discussing how this phenomenon manifests within a more natural global framework. We were interested in how the global context influences the magnitude and spatial extent of the illusion. To address this, we examined the WCI using a variety of 3D solid surfaces and objects (Exp 1) and wireframe versions of them (Exp 2) as compared to more traditional 2D stimuli while keeping local information nearly identical across conditions. We also explored how simple global stimulus changes to more traditional 2D stimuli can influence the WCI by splitting them into multi-part open-ended stimuli (Exp 3). Previous research indicated the WCI should spread outward in the absence of a physical border like in our open-ended stimuli. Contrary to previous literature we found color does not spread outside of most of these physically opened configurations demonstrating that global configuration is an important factor in how color spreading manifests. This study is one of the first to explore how contextual information more typical of our visual experience influences color spreading.

36.325 **Color AfterImages Determined in Non-Cardinal Color Axes** Clemente Paz-Filgueira[1](cpaz@uic.edu), Sarah Elliot[2], Michael Tan[1], Dingcai Cao[1]; [1]Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago, Chicago, IL, USA, [2]Department of Psychology, Roosevelt University, Chicago, IL, USA

INTRODUCTION: Complementary color afterimages appear after the removal of a bright stimulus from the visual field. Using a time-varying paradigm, Zaidi et al (Current Biology, 2012) found that adaptation within retinal ganglion cells may be sufficient to account for the appearance of color afterimages for stimuli modulating along the cardinal color axes of l (L/(L+M)) or s (S/(L+M)). The current study modulated stimuli along non-cardinal diagonal axes in MacLeod & Boynton cone chromaticity space to evaluate whether adaptation within higher order mechanisms contributes to color afterimages. METHODS: Subjects (3 males and 3 females) were presented stimuli consisting of two hemidisks subtending 3.6° on an equal energy white (EEW) background (20 cd/m2). The

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colors of the hemidisks were modulated complementarily by sinusoidal half-cycles (1/32 Hz) along one of five axes: (1) L+M+S, (2) l, (3) s, and two non-cardinal axes that modulated l and s simultaneously with the same contrasts as those modulations along the cardinal axes. The task of the observers was to indicate the time at which the two semicircles appeared the same shade of gray (identity point) using a face clock. For each axis, we tested four contrasts (L+M+S: 12.5%-50%; l: 2.9%-6.5%; s: 35%-80%). RESULTS: The time to reach the identity point increased linearly with stimulus contrast for all axes. The identity point was reached faster for stimuli along s-axis than for the non-cardinal axes under the same s-contrasts, whereas no difference was found between the non-cardinal and the l axes under the same l contrast. CONCLUSIONS. The time-varying afterimage for stimuli modulated along the non-cardinal color axes was determined by the cardinal mechanism with slower adaptation. This evidence indicates that adaptation within retinal ganglion cells is sufficient to account for the dynamics of color afterimages.

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36.326 **ChromaBlur: Rendering natural chromatic aberration drives accommodation effectively** Martin S Banks[1](martybanks@berkeley.edu), Steven A Cholewiak[1], Gordon D Love[2]; [1]Vision Science & Optometry, UC Berkeley, USA, [2]Physics & Computer Science, Durham University, UK

Retinal-image blur occurs when the eye is focused at one distance and an object is at another. Vision scientists and computer-graphics engineers often wish to create images that reproduce such depth-dependent blur, but their method is incorrect because it does not incorporate the human eye's optical aberrations. We developed a rendering method that, by incorporating these aberrations, creates displayed images that produce more natural retinal images. Here we concentrate on one aberration: longitudinal chromatic aberration (LCA). LCA creates different chromatic effects in the retinal image for objects farther vs nearer than current focus. We asked whether one can drive eye focus (accommodation) by incorporating LCA into the rendering of objects meant to appear farther or nearer than current focus. Observers viewed textured planes monocularly in three conditions: 1) Real Change in which stimulus focal distance actually changed; 2) Defocus Only in which focal distance did not change but blur rendering did (each color primary treated the same); 3) Defocus + LCA (we call this ChromaBlur) in which focal distance did not change but blur rendering did (appropriately for each primary). In one experiment, real or simulated distance changed sinusoidally over time. Accommodative gains and phases were essentially identical for Real Change and Defocus + LCA. There was no response with Defocus Only. In another experiment, we opened the loop by viewing with a pinhole aperture. There was no response for Real Change, but large, overshooting responses for Defocus + LCA. Finally, we measured responses in dichromats. They did not respond reliably to Defocus + LCA because of reduced ability to sample color signals. Our results show that appropriate rendering of chromatic aberration is very effective in driving accommodation, at least in color-normal observers. This motivates new techniques for blur rendering.

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36.327 **Changes in the pupillary and accommodative responses of the human eye under different illuminations** Maydel Fernandez-Alonso[1](maydel.fernandez-alonso@newcastle.ac.uk), Abigail P. Finch[2], Gordon D. Love[2], Jenny C. A. Read[1]; [1]Institute of Neuroscience, Newcastle University, Newcastle upon Tyne, UK, [2]Department of Physics, Durham University, Durham, UK

The human accommodation response has a consistent steady-state error over most of its range. For nearer distances, the response is less than required for perfect focus, and it is greater for farther distances. One hypothesis is that this results from the visual system implementing a strategy that exploits the eye's longitudinal chromatic aberration (LCA). For near targets, short-wavelength components are brought into focus, while for distant targets, long-wavelength components are in focus. To test this idea, we measured accommodation to a fixation target under monochromatic and polychromatic illumination at multiple distances. If different wavelengths are preferentially placed into focus at each distance, the response curve for monochromatic light should show a steeper slope than for polychromatic light. Dynamic measures of accommodation and pupil size were obtained from untrained observers with an infrared photorefractor. Monocular accommodation response curves were measured by changing the physical distance of the target from 0.5 to 3 diopters while keeping its angular size constant. For near targets under monochromatic light, observers accommodated appropriately to account for the changes in focus caused by LCA. However, the difference in refraction for different wavelengths progressively reduced as distance increased and by 2 metres, accommodation for all illuminations was the same. There was a significant effect of wavelength on pupil size, with smaller pupils for shorter wavelengths even when calculated luminance was equal. Accommodation to white light was comparable to that of green and orange lights at all distances, refuting the initial idea and indicating that a particular wavelength is not preferentially placed into focus in the retina as a function of distance.

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36.328 **Perceptual effects of delayed cone-opponent signals from an extended surround network: In memory of Daniel J. Plummer** Andrew Stockman[1](a.stockman@ucl.ac.uk), Bruce Henning[1], Andy T. Rider[1]; [1]Institute of Ophthalmology, University College London, England

Cone signals in the luminance or achromatic pathway were investigated by measuring how the perceptual timing of M- or L-cone-detected flicker depended on temporal frequency and chromatic adaptation. Relative timings were measured by superimposing either M- or L-cone-isolating flicker on "equichromatic" flicker (of the same wavelength as the background) and asking the observer to vary temporal contrast and phase to cancel the flicker as a function of temporal frequency. Measurements were made in four observers on up to 35 different backgrounds varying in wavelength from 410 to 658 nm and in radiance. Observers showed substantial perceptual delays or advances of L- and M-cone flicker that varied systematically with cone class, background wavelength, and radiance. Delays were largest for M-cone isolating flicker. Although the results appear complex, they can be accounted for by a surprisingly simple model in which the representations of L- and M-cone flicker are comprised of not only a fast copy of the flicker signal, but also a slow copy that is delayed by roughly 30 ms and varies in strength and sign with both background wavelength and radiance. The delays, which are too large to be accounted for by selective cone adaptation on chromatic backgrounds, must be postreceptoral. Clear evidence for the slow signals can be found in physiological measurements of horizontal and magnocellular ganglion cells, thus placing the origin of the slow signals in the retina—most likely in an extended horizontal cell network. These results suggest that under some conditions luminance-equated stimuli chosen to isolate the chromatic channels inadvertently generate slow signals in the luminance channel.

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36.329 **S-Cone Filling-in Studied with a Forced-Choice Method** Jingyi He[1](he.jing@husky.neu.edu), Yesenia Taveras Cruz[1], Rhea T. Eskew, Jr.[1]; [1]Department of Psychology, Northeastern University, Boston MA 02115

Sampling of the retinal image by the short-wavelength sensitive (S) cones is sparse, and vision mediated by S cones is of poor spatial resolution. When two small rectangles that differ only in S cone excitation are juxtaposed, chromatic discrimination between them is worse than when a visible gap or contour separates the two rectangles (Boynton et al., 1977); in the absence of the contour, a perceptual interpolation or filling-in process may reduce the apparent difference between the two sides. The present study began with the observation that when the top half of a black outline rectangle was filled with an S cone increment (S+, purplish), with the other half being an equiluminant gray, near threshold the purplish color seemed to adhere to the interior of the outline box at the top, as if the S cone signal spreads into the rectangle but is prevented from spreading outside the rectangle by the visible boundary. We used a 2TIFC method to explore this effect in several experiments, by measuring observers' ability to discriminate two stimuli, both of which were contained within a black outline rectangle. In one condition, half of the outline rectangle was filled with an S+ patch, fixed at detection threshold, and the other half was equi-

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luminant gray, with no visible contour between the two halves. The other, variable contrast stimulus was identical but the S+ patch filled only a quarter of the outline rectangle (adjacent to the outer edge), leaving 75% of the rectangle filled with gray. Discrimination threshold for the small and large patches is up to 3-fold higher than the detection threshold. These and other results suggest these chromatic patches are most visible near the outline rectangle's border, consistent with a spreading of the chromatic signal that is inhibited at visible contours.

Acknowledgement: NSF BCS-1353338

36.330 **Ambiguity contributes to grouping of color objects** Sunny Meongsun Lee[1](sunnylee@uchicago.edu), Emily Slezak[1], Steven K Shevell[1]; [1]University of Chicago

Grouping by similarity of a stimulus-level feature, such as chromaticity, can contribute to the perceptual resolution of multiple visually ambiguous objects (Wang & Shevell, VSS 2016). When two objects are presented with different degrees of ambiguity, the proportion of time the separate objects are grouped to give the same perceptual resolution is reduced compared to when both objects have the same degree of ambiguity (Grossman & Dobbins, 2003, Vision Research). The present study investigates whether the degree of ambiguity of an object is a stimulus-level feature itself that contributes to grouping and, if so, how it interacts with other stimulus features that contribute to grouping. Methods: Observers viewed multiple equiluminant chromatically-rivalrous discs that were exchanged between the eyes at 3.75Hz (i.e. in interocular switch rivalry) and reported whenever all discs were perceived to be a single color, either "red" or "green". These ambiguous chromatically-rivalrous discs could be presented together with unambiguous non-rivalrous colored discs. Up to 8 discs could be presented simultaneously, arrayed along a circular contour. Observers fixated at the circle's center. Five stimulus displays with different proportions of ambiguous and unambiguous discs were tested: 8 ambiguous discs, 7 ambiguous discs, 7 ambiguous discs with 1 unambiguous disc, 4 ambiguous discs with 4 unambiguous discs, and 4 ambiguous discs alone. Results/Conclusion: Including unambiguous colored discs reduced by 50% or more the time during which all discs were perceived to be the same color. This indicates that the stable unambiguous discs did not bias chromatic perceptual resolution of the rivalrous ambiguous discs. The proportion of ambiguous versus unambiguous discs had no significant effect. These results indicate that ambiguity itself is indeed a feature of an object used to group the objects so they are perceived to have a common color.

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36.331 **Separate color systems for different spatial scales** Laysa Hedjar[1,2](lh1976a@student.american.edu), Arthur G. Shapiro[1,2,3]; [1]Department of Psychology, American University, [2]Behavior, Cognition, and Neuroscience Program, American University, [3]Department of Computer Science, American University

Color constancy is often ascribed to higher-level perceptual inferences that allow the visual system to discount the illumination to estimate the reflectance of a material. However, our laboratory has suggested that much of what is required for color constancy is available in the spatial structure of the stimulus: chromatic content in the low spatial frequency (LSF) range corresponds roughly to the global illumination; chromatic content in the high spatial frequency (HSF) range remains roughly invariant to illumination changes. Here we examine the extent to which independent changes in the color of HSF and LSF content produce perceptual analogs of reflectance and illumination. Images were decomposed into spatial-band component images. The hue of the decomposed images were shifted in L*a*b* space (see Nascimento et al., 2017) and then images were recombined. Objects or shapes from the images were extracted and isolated on a gray background. Participants were asked to 1) match the isolated object to the same object within the manipulated image; 2) match the isolated object to the object isolated directly from the manipulated image on a gray background; and 3) adjust the hue of a white paper to appear as though it were under the same illumination as in the manipulated image. Results are plotted as a function of hue shift produced at each spatial band. Demonstrations produced from the images suggest that object color corresponds to HSF color and illumination corresponds to LSF color. More than that, swapping LSF content between images creates the impression of a change in illumination but not a change in object color, whereas swapping HSF content between images creates the impression of a change in object color but not in illumination. We speculate about the locus and function of the separation and recombination of distinct HSF and LSF color vision systems.

36.332 **Chromatic differences between colours retrieved from RGB and hyperspectral images** Joao Manuel Maciel Linhares[1](jlinhares@fisica.uminho.pt), Cristina Montagner[1], Ana Bailão[1,2,3], Nobuyo Okada[4], Kanako Maruchi[4], Taisei Kondo[5], Shigeki Nakauchi[5], Sérgio M. C. Nascimento[1]; [1]Centre of Physics, University of Minho, Portugal, [2]Faculty of Fine Arts, University of Lisbon, Portugal, [3]Research Center for Science and technology of the Arts- Portuguese Catholic University, Centre Regional of Porto, CITAR, Portugal, [4]Toyohashi City Museum Art and history, JAPAN, [5]Toyohashi University of Technology, JAPAN

The common RGB digital camera (DC) is able to compress all the surrounding spectral information into a trichromatic system capable of represented the majority of the perceived colours. It follows the same compression philosophy as the human eye, where the spectral information is compressed into a three-dimensional color system. Despite the same apparent solution to compress the spectral information, the human eye and the DCs possess different spectral sensitivities and, in the end, provide different chromatic experiences. To which extend the human eye and the DCs provide the same chromatic capabilities, is still an open question. The spectral information of 50 hyperspectral images of natural scenes and 78 art paintings was used to estimate the chromatic differences between the human eye and a DC assuming the CIE D65 illuminant and the CIE1931 2º standard observer. The human eye chromatic diversity was estimated by computing the tristimulus values from the reflectance data. The DC chromatic diversity was estimated by assuming the spectral sensitivity of the DC to estimate the RGB colour from the spectral data and then converting it into the tristimulus values. The CIELAB chromaticity coordinates were then computed, as the pixel colour difference (ΔE*ab) between the human eye and the DC. The ΔE*ab was assumed as a metric of the chromatic differences. It was found that the chromatic differences between the two systems were higher for paintings than for natural scenes. A Pseudo Voigt fit to the frequency distributions of the ΔE*ab between the human eye and the DC estimated the peak at about 6.70 (±0.06) and 3.56 (±0.07) ΔE*ab for art paintings and natural scenes, respectively. These results seem to indicate that DCs may provide better chromatic estimations on natural scenarios than on art paintings, when compared with the accuracy of hyperspectral imaging.

36.333 **PsychoPysics: a suite of tools for teaching Psychophysics using PsychoPy** James A Ferwerda[1](jaf@cis.rit.edu); [1]Center for Imaging Science, Rochester Institute of Technology

Teaching psychophysics is challenging, because while hands-on experience is the best teacher, easy-to-use platforms for developing and running experiments are not readily available. To address this problem, (Ferwerda (2015) J. Vision, 15(12):476), introduced the FechDeck, a literal hands-on platform for teaching psychophysics based on a deck of playing cards. While the FechDeck provided direct experience with psychophysical methods, for good or ill, it did not introduce them in the computer-based milieu commonly used in practice. PsychoPy (Pierce (2007), J. Neuro. Meth., 162(1-2):8-13), is an open-source, multi-system, computer-based platform for experimental psychology, that facilitates experimentation with both graphical and code-based interfaces. The focus of this project, PsychoPysics, is a suite of PsychoPy experiments and related analysis tools for teaching computer-based psychophysics. The current suite includes PsychoPy experiments that implement standard threshold methods (adjustment, limits, constant stimuli), scaling methods (rating, pair comparison, magnitude estimation), and concepts in signal detection theory. The data produced by the experiments (stored in .csv files) can be analyzed and visualized using the provided Excel spreadsheets, or processed by other tools. Students with or without coding experience, can explore the PsychoPy/PsychoPysics environment, run the experiments and analyze the data, modify the experiments to develop their own, and gain further understanding of the methods of psychophysics.

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Eye Movements: Pursuit, vergence, blink

Sunday, May 20, 2:45 - 6:45 pm, Banyan Breezeway

36.334 **Novel Blink Detection Method Based on Pupillometry Noise** Ronen Hershman[1,2](ronenhe@post.bgu.ac.il), Avishai Henik[2,3], Noga Cohen[4]; [1]Department of Cognitive and Brain Sciences, Ben-Gurion University of the Negev, Beer-Sheva, Israel, [2]Zlotowski Center for Neuroscience, Ben-Gurion University of the Negev, Beer-Sheva, Israel, [3]Department of Psychology, Ben-Gurion University of the Negev, Beer-Sheva, Israel, [4]Department of Psychology, Columbia University, New York, USA

Pupillometry (or measurement of pupil size) is commonly used as an index of cognitive load and arousal. Pupil size data is recorded using eye-tracking devices that provide an output containing pupil size at various points in time. During blinks, the eye-tracking device loses track of the pupil and this results in missing values in the output file. The missing-samples time window is preceded and followed by a sharp change in the recorded pupil size, due to the opening and closing of the eyelids. This eyelid signal can create artificial effects if it is not removed from the data. Thus, accurate detection of the onset and the offset of blinks is necessary for pupil size analysis. While there are several approaches to detecting and removing blinks from the data, most of these approaches do not remove the eyelid signal or they result in a relatively large data loss. The current work suggests a novel blink detection algorithm based on the fluctuations that characterize pupil data. These fluctuations ("noise") result from a measurement error produced by the eye-tracker device. Our algorithm finds the onset and offset of the blinks based on this fluctuation pattern and its distinctiveness from the eyelid signal. By comparing our algorithm to three other common blink detection methods and to two independent human raters, we demonstrate the effectiveness of our algorithm in detecting blink onset and offset.

36.335 **Role of SEF on attentional distribution during smooth pursuit eye movements** Zhenlan Jin[1](jinzl@uestc.edu.cn), Xuejin Ni[1], Junjun Zhang[1], Ling Li[1]; [1]Key Laboratory for NeuroInformation of Ministry of Education, School of Life Science and Technology, Center for Information in Medicine, University of Electronic Science and Technology of China

It has been showed that more attention is distributed in front compared to behind of the pursuit stimuli. Supplementary eye field (SEF) is know to be involved in the cognitive aspect of smooth pursuit system. We hypothesize that disturbing the activities of SEF would modulate the attentional distribution during pursuit. Therefore, we designed a dual task paradigm which required subjects to perform smooth pursuit and detection tasks simultaneously. In the study, a green cross moved horizontally and a red dot briefly appeared around the cross during the movement. Also, placeholders indicating possible locations of the red dot either moved with the green cross or were not presented. The subjects were required to smoothly pursue the green cross and press a button quickly upon the appearance of the red dot. Before conducting the experiment, we stimulated the SEF using TMS. We found that responses to the red dot were faster when it appeared in front compared to behind of the cross, named as frontal advantage, and the stimulation over the SEF lessened the frontal advantage. In addition, the presence of the placeholders boosted the steady-state velocity gain of the pursuit and the stimulation of the SEF reduced the velocity gain only when the placeholders were presented. These results suggest that the SEF plays a role in controlling of the feedforwad gain of the pursuit system and also influences attentional distribution during the pursuit.

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36.336 **Am I going fast enough to enter the traffic circle? Judging the relative velocities of moving objects** Jie Wang[1](jie.zy.wang@rutgers.edu), Eileen Kowler[1]; [1]Department of Psychology, Rutgers University, Piscataway, NJ

Visuomotor tasks often require estimating how fast one object moves relative to another. To study such judgments, and the eye movement strategies, subjects saw two discs moving toward a common meeting point (MP) on a diamond-shaped "traffic circle" (overhead view). Discs started moving either from the top or from below the bottom of the diamond. Performance in a baseline velocity discrimination task (reporting which disc would arrive at the MP first) was precise (6-7%), with no bias toward either disc. A more challenging "collision" task required a 3-category judgment: top disc first vs. bottom disc first vs. collision. Collisions were defined as any overlap of the discs at the MP. Overlap occurred when disc velocities differed by < 6.25%. Velocity discrimination in the collision task was as precise as in the baseline. However, category boundaries were inaccurate, with large biases to report "collision". Collisions were reported for velocity differences up to 10%, despite feedback on each trial. Results were similar when the task required a motor action, namely, stop the bottom disc if a collision seemed likely. Reaction times were longest in the collision task due to the additional response categories. Eye fixation remained near the MP in all tasks. Smooth pursuit was rare until after the decision was made, when the discs moved as a pair. These results show that visual system can support more complex motion judgments, such as adding response categories and evaluating the magnitude of velocity differences, without loss of precision. The observed biases to favor "collision" judgments in the 3-category task may have been a response to high levels of uncertainty when velocity differences were close to the collision boundary. Such conservative criteria may be useful in real-world equivalents of the task.

36.337 **Assessing Strategies for Involuntary Saccadic Control during Pursuit of Transiently Occluded Targets** Conor V Shea[1,2](cvshea@bu.edu), Daniel Bullock[3], Arash Yazdanbakhsh[2,3,4,5]; [1]Program in Neuroscience, Boston University, [2]Vision Lab, Center for Research in Sensory Communications and Neural Technology (CReSCNT), Boston University, Boston, MA 02215, [3]Department of Psychological & Brain Sciences, Boston University, [4]Center for Systems Neuroscience, Boston University, Boston, MA 02215, [5]Graduate Program for Neuroscience, Boston University, Boston, MA 02215

INTRODUCTION The diagnosis of Parkinson's Disease (PD) occurs after symptoms are present; therefore, predicting PD emergence is critical. PD often includes ocular symptoms: nystagmus, difficulty initiating and maintaining smooth pursuit, and more saccades during pursuit. We studied control behavior during a pursuit task for future comparison with PD patients, assessing how inter-trial interval (ITI) affected tracking of a target that deflected behind an occluding wedge. METHODS Eye tracking of eight subjects was performed using the Eyelink II (500 Hz). In the first task, a target travelled horizontally behind occluders of various sizes (2-6°, 6 trials/occluder). To guarantee saccades during occlusion in the second task, we chose the minimum wedge size resulting in saccades during occlusion at least five of six trials. In the second task, the target deflected behind the wedge diagonally up or down with unequal probability (11 versus 4 of 15 trials). After 15 trials, the more frequent direction covertly flipped and the ITI lengthened from 10 to 15 seconds. We measured saccade latency (time between target reappearance and catch-up saccade to the target) and post-saccadic error across trials. RESULTS Among more-frequent deflection trails, saccade latency decreased significantly across the first set of 15 trials (ITI = 10s) [p=0.025], but latency was constant at a higher level across the second set of 15 trials (ITI = 15s). Post-saccadic error marginally increased across the first set of 15 trials (p=0.09), but did not change across the second set of 15 trials. CONCLUSION Subjects' latency and post-saccadic error changed most across the first half of trials, indicating that subjects honed their tracking strategy during the first half of trials. The increased post-saccadic error and decreased saccadic latency implies an increasing reliance on a predictive tracking strategy, as subjects grew more confident in the higher-frequency deflection.

36.338 **The relative contributions of area MT and the frontal eye fields to the latency of smooth pursuit** J. Patrick Mayo[1](mayo@neuro.duke.edu), Stephen G. Lisberger[1]; [1]Department of Neurobiology, Duke University

Correlated features of neuronal activity place important constraints on how the brain uses sensory information to guide behavior. While the majority of research on correlations so far has focused on the size of neuronal responses (e.g., spike count correlations), here we focus on correlations between the timing of responses between cortical neurons and

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their relation to the initiation of smooth pursuit eye movements. Previous work demonstrated that some of the variability in the timing of pursuit initiation could be accounted for by variability in the timing of neuronal responses in area MT. Our goal was to determine whether correlations between sensory encoding variability and movement variability are maintained in downstream brain areas and across cortical regions. We recorded simultaneously in areas MT and the smooth pursuit eye movement region of the frontal eye fields (FEFsem) in rhesus monkeys using 24-channel Plexon V-probes. Monkeys were trained to fixate in the center of a video display and then pursue a patch of dots at various speeds and directions. Trials with saccades during stimulus motion onset or pursuit initiation were excluded, and we collected approximately 100 trials per stimulus condition. We shifted and scaled each trial's eye speed trace and neuronal response to fit the data from all trials to obtain precise latency and amplitude estimates (Lee et al., Neuron, 2016). We found that the response latencies of pairs of MT neurons and pairs of FEFsem neurons during pursuit initiation were positively correlated. The amplitudes of neuronal responses were also positively correlated in MT and FEFsem, but neuronal amplitude was not correlated with the time of pursuit initiation. Response timings of MT-FEFsem neuron pairs were not correlated, suggesting that MT and FEFsem contribute independently to the timing of pursuit initiation.

36.339 **Eye Movement Correlates of Figure-Ground Segregation and Border-Ownership** Mohammad Keshtkar[1,2](keshtkar@bu.edu), Shigeaki Nishina[3], Arash Yazdanbakhsh[2,4,5,6]; [1]Program in Neuroscience, Boston University, [2]Vision Lab, Center for Research in Sensory Communications and Neural Technology (CReSCNT), Boston University, Boston, MA 02215, [3]Honda Research Institute Japan Co., Ltd., address: 8-1 Honcho, Wako-Shi, Saitama 351-0188, [4]Department of Psychological & Brain Sciences, Boston University, [5]Center for Systems Neuroscience, Boston University, Boston, MA 02215, [6]Graduate Program for Neuroscience, Boston University, Boston, MA 02215

Oculomotor system controls human eye movements while scanning a scene. One cue used by visual system to make sense of a scene is the border of objects. Our goal is to understand whether oculomotor system has any pre-set predictions while mapping out a scene. To test this hypothesis, we designed a set of 3D scenes by using an integrated 3D projection and eye-tracking system to compare human eye movement patterns during depth cue consistent occlusion (CCO) and inconsistent occlusion (CIO) of a moving target in a pursuit task. In CCO, the moving target gets occluded by an object in front of it or will remain visible if the object is behind. However, in CIO, the moving target gets occluded by an object behind it or will remain visible if the object is in front. It has been known that when a moving target becomes invisible midway on its path, eye pursuit switches to saccades. In this study, we found that least switches to saccades occur in CCO and when the pursuit target is visible. On the other hand, the maximum switches to saccades occur during CIO when the pursuit target is invisible. Saccadic interruption increases slightly in CIO where the target is visible, and even more so in CCO when the target is invisible. We conclude that during scanning a visual scene, human oculomotor system utilizes a set of predictions, perhaps based on accumulated previous experiences, such as "when a moving target goes behind an occluder it should disappear", and when the predictions are challenged, the oculomotor system switches pursuit to saccade. Finally, we present a set of metrics to quantify the interactions between visual-system-based scene segmentation and eye movement patterns, and the interactions between border-ownership and eye movement vectors to establish eye movement correlates of figure-ground segregation and border-ownership.

Acknowledgement: Honda Research Institute, Japan

36.340 **Pursuit eye movements enhance decision making and hitting accuracy in a go/no-go manual interception task** Jolande Fooken[1,2](jolande.fooken@rwth-aachen.de), Miriam Spering[1,2,3,4]; [1]Dept. Ophthalmology & Visual Sciences, University of British Columbia, Vancouver, Canada, [2]Graduate Program in Neuroscience, University of British Columbia, Vancouver, Canada, [3]Center for Brain Health, University of British Columbia, Vancouver, Canada, [4]Institute for Computing, Information and Cognitive Systems, University of British Columbia, Vancouver, Canada

It is well established that eye and hand movements are closely coupled in space and time—the eye saccades to and fixates on task-relevant object locations and leads the hand during reaching, grasping, or pointing movements. However, the relation between smooth pursuit and hand movements in response to dynamic visual targets is less well understood. Here, we investigate the relation between smooth pursuit and interception performance in a go/no-go manual interception task. We focus on two aspects of performance: the decision whether or not to move the hand, and the accuracy of the interception. Observers (n=10) viewed a small target moving along a linear path that either projected into a strike zone (hit) or went past it (miss); observers were instructed to intercept only in hit trials, and to not move their hand in miss trials. The target was shown for the full path to the strike zone, or for ¼, ½, or ¾ of the full trajectory. Eye movements were manipulated in separate blocks by instructing observers to maintain fixation on a stationary fixation cross, randomly positioned at three locations along the trajectory, or to move their eyes freely. Across conditions, better and faster pursuit (lower 2D position error, higher eye velocity) and more accurate fixation were linked to better decision and hitting accuracy. Importantly, engaging in smooth pursuit eye movements as compared to fixation resulted in a significant performance improvement across all observers. This pursuit benefit was of the same magnitude (8% average improvement in pursuit vs. fixation) with regard to decision making and hitting accuracy. These results underline the critical importance of smooth pursuit in guiding movement decisions and execution. They also imply that efference-copy signals, generated by the pursuit system, act early on the perceptual system to inform the decision whether or not to initiate a movement.

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36.341 **Humans compensate for the angular acceleration of an approaching ball-in-flight by coupling movement of the gaze vector to the ball's rate of optical expansion.** Gabriel J Diaz[1](gabriel.diaz@rit.edu), Catherine A Fromm[1]; [1]Center for Imaging Science, RIT

Although research on human oculomotor control has found low sensitivity to acceleration, humans in natural environments have little trouble tracking a ball approaching in depth prior to an attempted catch. This is surprising because a ball moving along even a constant velocity through Euclidean space will undergo high values of angular acceleration as it moves towards a location near to the head. In this study, we test the hypothesis that humans compensate for the ball's angular acceleration by coupling movement of the gaze vector to the ball's pattern of optical expansion - a perceptual covariate of optical acceleration due to movement in depth. To test this hypothesis, subjects immersed in a virtual reality ball catching simulation were tasked with catching a ball that travelled to one of three locations at distances scaled to the subject's maximum reach. Arrival height was randomized within a range centered around head height. Although initial ball radius (cm) was constant, modified expansion rates were brought about by algorithmic manipulation of the ball radius through deflation/inflation during flight, consistent with the application of a gain term (δ) to the expansion rate. A gain of 1 is a consistent with the natural rate of expansion of an approaching constant sized ball, $\delta < 1$ is diminished expansion due to deflation, and $\delta > 1$ is exaggerated expansion due to inflation. Subjects performed 10 repetitions at gain values of 0.5, 0.75, 1, 1.25, and 1.5 (3 passing distances x 5 gain x 10 repetitions = 150 trials per subject). The results indicate that the gaze vector shifted further along the ball's trajectory at greater values of δ,

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consistent with the hypothesis that subjects in the natural context account for angular acceleration by coupling movement of the gaze vector to the ball's rate of angular expansion.

36.342 **Judgments of a target's speed are more precise when the eyes pursue the target** Cristina de la Malla[1], Jeroen B.J. Smeets[1], Eli Brenner[1]; [1]Department of Human Movement Sciences, Vrije Universiteit Amsterdam

If we want to successfully intercept a moving target, we need an accurate and precise estimate of the velocity at which it moves. Although we normally look at targets that we want to intercept, it is still unclear whether pursuing targets with one's eyes leads to better judgements about how fast they are moving. Judgments might depend on what the eyes are doing, because when pursuing the target with one's eyes, one judges the target's motion from signals related to the movements of the eyes, rather than relying on the retinal slip of the target's image. Previous studies have shown that pursuing a moving target with one's eyes can influence how fast it appears to move, but none have examined how doing so influences the precision with which its velocity can be judged. Here we use a two alternative forced choice discrimination task in which subjects had to judge which of two sequentially presented moving bars moved faster. Each presentation consisted of a static bar at the centre of the screen and a moving bar that moved through the static bar as it moved from left to right across the screen. In different sessions subjects had to either fixate the static bar or pursue the moving bars. One of the two sequentially presented moving bars moved at 5, 10 or 20º/s. The other moved either 10, 30 or 50% slower or faster. We fit psychometric curves to the responses to estimate the precision with which the velocity was judged. Subjects judged the velocity of the moving bars about 10% more precisely when they were pursuing the moving bars with their eyes.

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36.343 **Reinforcement contingencies affect pursuit target selection in healthy and Parkinson's disease participants** Jean-Bernard Damasse[1](jean-bernard.damasse@univ-amu.fr), Gurkiran K Mann[2], Christina B Jones[3], Martin J McKeown[3], Miriam Spering[2], Montagnini Anna[1]; [1]Institut de Neurosciences de la Timone, CNRS – Aix-Marseille University, Marseille, France, [2]Dept. of Ophthalmology & Visual Sciences and Center for Brain Health, University of British Columbia, Vancouver, Canada, [3]Department of Medicine (Neurology), Pacific Parkinsons Research Centre, The University of British Columbia, Vancouver, BC V6T 2B5, Canada.

Voluntary eye movements are sensitive to reward contingencies (e.g. Madelain et al, 2011). Here we used smooth pursuit eye movements to investigate responses to visual targets associated with different probabilities of monetary gain or loss. Smooth pursuit allows a continuous read-out of processing cognitive information, such as reward, from the earliest phase of the response prior to target onset (anticipatory pursuit) to visually-guided steady-state pursuit of a selected target. In a novel task, inspired by the Iowa Gambling Task (IGT, Bechara et al., 1994), observers had to fixate in the screen center while two targets moved towards fixation from different directions. Once the targets reached fixation, observers had to select one and track it with their eyes. Importantly, in the main experiment, each target's direction was associated with a different stochastic reinforcement rule, either advantageous, yielding an overall gain across trials, or disadvantageous, yielding an overall loss. In a control experiment, the target was explicitly instructed (e.g. "Follow the black target") with no association between target selection and reward. Participants were patients diagnosed with Parkinson's disease (PD), a neurodegenerative movement disorder that is also frequently associated with impaired ability to assess risk, tested both ON and OFF medication. We also tested age-matched and young healthy controls. For all groups, choice latency (the delay after which the oculomotor target selection becomes evident) was clearly shortened in the IGT-pursuit task compared to the control-task. Moreover, eye movements deviated toward the selected target direction already in the anticipatory phase. However, early visually-guided smooth pursuit underwent a significantly stronger bias toward the selected direction in young controls than in PD patients the age-matched controls. The analysis of target selection strategy with respect to the reinforcement rule revealed a consistent impairment in decision-making for PD patients.

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36.344 **Anisotropic gaze adaptation in reflexive and voluntary blinks** Wee Kiat Lau[1](wlau010@e.ntu.edu.sg), Gerrit W Maus[1]; [1]Nanyang Technological University (Psychology, School of Social Sciences)

The oculomotor system re-calibrates gaze position when a fixation target changes position during blinks, although observers are unaware of the displacement (Maus et al., Current Biology 27, 445–450, 2017). This previous study only tested rightward displacements during spontaneous eye blinks. Does "blink adaptation" (BA) also occur equally for other displacement directions and for reflexive eye blinks? Participants (N = 20) observed a white dot on a black screen that repeatedly displaced by 0.7° in the same direction during each blink. Participants completed blocks of displacements in all cardinal directions (upward, downward, rightward, leftward) for voluntary blinks, and for reflexive eye blinks triggered by an air puff to the eyelid. We measured gaze positions after blinks in the right eye and assessed BA by comparing gaze positions between baseline conditions and after adaptation. Results illustrated significant BA in all directions, but also significant differences between directions: BA was largest for downward and rightward (i.e., temporal in the right eye) directions, smaller for upward and leftward (i.e., nasal). We found no within-subject differences in BA between reflexive and voluntary/spontaneous blinks, although only the rightward displacement direction showed significant BA for reflexive blinks. Adaptation to reflexive blinks was potentially contaminated by intervening voluntary blinks; the dot was only displaced during reflexive blinks. Our results add evidence that the oculomotor system re-calibrates gaze position to compensate for oculomotor errors during blinks, regardless whether these are triggered voluntarily/spontaneously or reflexively via an external stimulus. Evidence of anisotropies across different displacement directions indicates that oculomotor constraints of blink-related eye movements play a role in the effectiveness of gaze re-calibration across blinks.

Faces: Emotions

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36.345 **Spatial frequencies for accurate categorization and discrimination of facial expressions** Isabelle Charbonneau[1](chai22@uqo.ca), Stéphanie Cormier [1], Joël Guérette[1], Marie-Pier Plouffe-Demers[1], Caroline Blais[1], Daniel Fiset[1]; [1]Université du Québec en Outaouais

Many studies have examined the role of spatial frequencies (SFs) in facial expression perception. However, most of these studies used arbitrary cut-off to isolate the impact of low and high SFs (De Cesarei & Codispoti, 2012) thus removing possible contribution of mid-SFs. This present study aims to reveal the diagnostic SFs for each basic emotion as well as neutral using SFs Bubbles (Willenbockel et al., 2010). Forty participants were tested (20 in a categorization task, 20 in a discrimination task; 4200 trials per participant). In the categorization task, subjects were asked to identify the perceived emotion among all the alternatives. In the discrimination task, subjects were asked, in a block-design setting (block order was counterbalanced across participants), to discriminate between a target emotion (e.g fear) and all other emotions. Mean accuracy was maintained halfway between chance (i.e. 12.5% and 50% correct for each task, respectively) and perfect accuracy. In both tasks, accuracy for happiness and surprise is associated with low-SFs (peaking at around 5 cycles per face (cpf); Zcrit=3.45, p< 0.05 for all analysis) whereas accuracy for sadness and neutrality is associated with mid-SFs (peaking between 11.5 and 15 cpf for both tasks). Interestingly, the facial expressions of fear and anger reveal significantly different patterns of use across task. Whereas their correct categorization is correlated with the presence of mid-to-high SFs (peaking at 14 and 20 cpf for angry and fear, respectively) their accurate discrimination is correlated with the utilization of lower SFs (peaking at 4 and 3.7 cpf). These results suggest that the visual system is able to use low-SF

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information to detect and discriminate social threatening cues. However, higher-SFs are probably necessary in a multiple-choices categorization task to allow fine-grained discrimination.

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36.346 **Spatial frequencies for the visual processing of the facial expression of pain** Joël Guérette[1](joel.guerette@uqo.ca), Stéphanie Cormier[1], Isabelle Charbonneau[1], Caroline Blais[1], Daniel Fiset[1]; [1]Département de psychoéducation et de psychologie, Université du Québec en Outaouais

Recent studies suggest that low spatial frequencies (SFs) are particularly important for the visual processing of the facial expression of pain (Wang et al., 2015; 2017). However, these studies used arbitrary cut-off to isolate the impact of low (under 8 cycles per faces (cpf)) and high (over 32 cpf) SFs, thus removing any contribution of the mid-SFs. Here we compared the utilization of SFs for pain and other basic emotions in three tasks (20 participants per task), that is 1) a facial expression recognition task with all basic emotions and pain, 2) a facial expression discrimination task where one target expression needed to be discriminated from the others and 3) a facial expression discrimination task with only two choices (i.e. fear vs. pain, pain vs. happy). SF Bubbles were used (Willenbockel et al., 2010), a method which randomly samples SFs on a trial-by-trial basis, enabling us to pinpoint the SFs that are correlated with accuracy. In the first task, accurate categorization of pain was correlated with the presence of a large band of SFs ranging from 4.3 to 52 cpf peaking at 14 cpf (Zcrit=3.45, $p< 0.05$ for all analysis). In the second task, the correct discrimination of pain was correlated with the presence of a band of SFs ranging from 5 to 20 cpf peaking at 11 cpf. In the third task, we computed the classification vectors for pain-happiness and pain-fear conditions and revealed the overlapping SFs. In this task, SFs ranging from 2.7 to 13 cpf peaking at 7.3 cpf are significantly correlated with pain discrimination. Our results highlight the importance of the mid-SFs in the visual processing of the facial expression of pain and suggest that any method removing these SFs offers an incomplete account of SFs diagnosticity.

36.347 **A Gaze-Contingent Investigation of the Effect of Perceptual Field Size on Processing Identity and Expression of Faces** Jin-Rong Lu[1,2](jinronglu14@gmail.com), Gary C.-W. Shyi[1,2]; [1]Department of Psychology, National Chung Cheng University, Chiayi, Taiwan, [2]Center for Research in Cognitive Sciences, National Chung Cheng University, Chiayi, Taiwan

It is widely believed that recognition of face identity is achieved via holistic processing of the representation integrated over parts of a face, whereas processing of facial expressions can be undertaken based on representation of separate parts. In two experiments, we examined how perceptual field may affect processing identity and expression of faces by using gaze-contingent control display in conjunction with an adaptive up-down procedure to adjust the size of perceptual field. In Experiment 1, we created a baseline condition to assess the size of perceptual field required for processing face identity. The results indicated that on average participants needed a perceptual field of about 2.54° of visual arc to process face identity. Moreover, although there was a tendency for participants to evenly distribute their eye movements among various parts of a face, the eyes appeared to play a slightly greater role than nose and mouth for identifying a face. The results of Experiment 2, on the other hand, indicate that (a) in judging whether a face was happy, participants would disproportionally rely upon the mouth region with a minimal size of perceptual field (0.63°), and (b) in judging whether a face was sad, both the eye regions and the mouth were critical to arrive at that judgment, and it required a substantially larger perceptual field (2.26°). These findings were further corroborated from results of temporal analyses of eye movements, showing the dynamic changes in processing different regions of a face for identifying specific facial expression. Taken together, these findings not only provide further evidence to lend support to the notion that processing identity and expression of faces may require different styles of processing (holistic vs. analytic) but also point out in details how judgment of various facial expressions may require different sizes of perceptual field.

36.348 **Effects of face direction and duration in facial emotion estimation Moeka Nakajima, Katsunori Okajima** Moeka Nakajima[1](nakajima-moeka-yg@ynu.jp), Katsunori Okajima[1]; [1]Yokohama National University

Facial emotion plays an important role in nonverbal human communication. There are a large number of studies on how facial emotion is estimated in our brains by using frontal facial images. However, we mostly observe non-frontal faces and it has not been clear how much we can estimate the facial emotion of side faces. To clarify the influence of the face direction and the presentation time on the estimation accuracy of human facial emotion, we conducted an experiment by using 3D images of human faces. We used a 3D scanner for the acquisition of 3D images of human faces which have several kinds of expressions. By rotating the 3D models horizontally or vertically, we made visual stimuli of some kinds of side faces and leaned faces. In the experiment, participants chose an expression label after observing a stimuli image. The condition of duration were 100ms and 2000ms. Results showed that the estimation accuracy of facial expression labelled "happy" did not depend on the horizontal rotation angle of side faces whereas the recognition accuracy of other facial expressions decreased with increasing the rotation angle from the front. In particular, the response of "anger" in the estimation increases with increasing the horizontal rotation angle of the face. In addition, it was found that estimation accuracy of the facial emotion as a function of the vertical rotation angle of leaned faces depends on the kind of emotion. Moreover, it was found that the estimation accuracy of the "happy" emotion did not depend on the presentation time while the estimation accuracy at the short presentation time (100ms) is lower than that at the long presentation time (2000ms). These results suggest that independent estimation mechanisms exist for each facial emotion in our visual system.

36.349 **Perceived gaze direction affects basic cognitive and affective theory of mind processes – an ERP study** Sarah D McCrackin[1](sdmccrac@uwaterloo.ca), Roxane J Itier[1]; [1]University of Waterloo

We look at someone's eyes for insight into their mental state. However, little is known about how seeing someone look at or away from us impacts our reasoning about their thoughts (cognitive theory of mind; cTOM) and emotions (affective theory of mind; aTOM). We examined how gaze affects the ability to make cTOM and aTOM judgements and the time course of these cognitive processes. As we usually infer what people are thinking based on where they are looking in their environment, we hypothesized that averted gaze may facilitate cTOM more than direct gaze. In contrast, direct gaze is implicated in emotional responding, suggesting a facilitatory role in aTOM. Thirty participants viewed the same direct and averted gaze faces expressing joy or anger (half female) and completed: 1) an aTOM task (emotion discrimination), 2) a cTOM task (direction of attention discrimination), and 3) a control task (gender discrimination). ERPs were recorded to face onset, and mean amplitude was analysed across 200ms time-windows from 200-800ms over occipito-temporal and parietal sites. Accuracy and reaction times were best/shortest for the control task, intermediate for the aTOM task, and worst/longest for the cTOM task. At occipito-temporal sites, task affected amplitudes around 400-800ms, with the most negative amplitude seen for the cTOM task, followed by the aTOM task, and then the control task, likely reflecting cognitive load. As predicted, gaze direction modulated behaviour in the two TOM tasks, but not the control task. Participants responded faster and more accurately when faces had direct gaze in the aTOM task, and when faces had averted gaze in the cTOM task. An increased positivity was elicited by direct compared to averted gaze in the cTOM task from 600-800ms over parietal sites. Results support a facilitatory role of direct gaze in aTOM and for averted gaze in cTOM tasks.

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36.350 **Deep Neural Network Identifies Dynamic Facial Action Units from Image Sequences** Tian Xu[1](tian.xu@glasgow.ac.uk), Oliver Garrod[1], Chaona Chen[1], Rachael E Jack[1], Philippe G Schyns[1]; [1]Institute of Neuroscience and Psychology, University of Glasgow, Scotland, UK

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The face is equipped with a large number of independent muscles that generate observable face movements such as nose wrinkling or smiling. These individual movements are called Action Units (AUs) in the Facial Action Coding System (FACS). FACS identifies about 40 AUs, each one of which has a variable amplitude. Here, we developed a two-stage deep neural network (DNN) that accurately categorized the underlying AUs from a sequence of image frames. We first trained a 10-layer ResNet AU decoder with 800,000 independent facial images of randomly activated AU combinations. Each image was generated by a 3D animation system that rendered the combination of up to 4 randomly selected AUs (from 42 possible AUs) with variable amplitude. The training outputs were the predicted amplitudes (range 0~1) of each AU (42 AUs). We next trained a LSTM (Long Short Term Memory) network to aggregate the predicted AU amplitudes learned from multiple images (i.e. a sequence of 30 frames) via ResNet. The final output is a binary AU vector that indicates the activated AUs over the sequence. We test our DNN on a dataset of 720 dynamic facial expression models, where each face model consists of 30 sequential image frames and the corresponding activated AUs. The d' of each AU's prediction demonstrates that the prediction of most AUs are reliable. Moreover, by comparing the representational dissimilarity matrices (RDMs) between each pair of AU vectors, we can observe that the output similarity pattern matches the input. To our knowledge, the proposed two-stage DNN is the first network to treat the AU prediction as a decoder problem, which can not only predict the activation of AUs, but also can predict the amplitude of activation for multiple AUs. This work will help further in decoding the relationship between emotion and action units.

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36.351 Are face identity and expression processed independently or interactively? A study controlling stimulus and decisional factors

Claudia G. Wong[1](cwong029@fiu.edu), Fabian A. Soto[1]; [1]Department of Psychology, Florida International University

In the last thirty years, the question of whether face identity and emotional expression are processed independently or interactively has garnered much attention, and a large number of studies have been performed to answer it. Although recent reviews conclude that identity and expression are processed interactively, the behavioral literature is plagued by contradictory results. This may be due in part to the lack of control of stimulus and decisional factors in most studies. An ideal experiment should (at the very least) control for several stimulus factors, including low-level changes correlated with identity (e.g., facial hair, shading, skin color and texture, etc.), strength of the expression shown by different actors, and discriminability of the two dimensions. Additionally, the experimental design and analysis should allow dissociating perceptual from decisional processes. To the best of our knowledge, no previous study has achieved this level of control, and without it any observed interaction could be explained by stimulus and decisional factors, rather than perceptual processing. Here, we created three-dimensional artificial face models and expression pose models (based on face photographs from the KDEF database) that allow for tight control of all the aforementioned stimulus factors. We obtained two sets of four stimuli, each resulting from the combination of two emotional expressions (neutral and angry) and two identities. Using face morphing, and guided by psychometric data from a pilot study, we manipulated the difference between the two levels of emotion and identity so that average discriminability was the same for the two dimensions. Participants were asked to complete an identification task involving the resulting stimulus sets, and the data was analyzed using a general recognition theory model (GRT-wIND) that allows to dissociate perceptual from decisional factors in the study of dimensional interactions. Under such tight experimental control, the dimensions were found to be perceptually separable.

36.352 Ten angry men: Serial reproduction of faces reveals that angry faces are represented as more masculine

Stefan Uddenberg[1](stefan.uddenberg@yale.edu), Brian Scholl[1]; [1]Department of Psychology, Yale University

Men are angry. That, at least, is a common stereotype relating gender and emotion. But how is this stereotype realized in the mind? It could reflect a judgmental bias, based on conceptual associations in high-level cognition. But another possibility is that it is (also) more deeply ingrained, such that we actually see male faces as angrier, as a consequence of relatively automatic aspects of visual perception. We explored this using the method of serial reproduction, where visual memory for a briefly presented face is passed through 'chains' of many different observers. Here, a single face was presented, with its gender selected from a smooth continuum between Female and Male. In an exceptionally simple task, the observer then just had to reproduce that face's gender by morphing a test face along the gender continuum using a slider. Critically, both the initially presented face and the test face could (independently) have an Angry or Happy expression, which the participant could not change. Within each chain of observers, these expressions were held constant, while the gender of each initially presented face was determined by the previous observer's response. In most cases, the chains merely converged on a region toward the midpoint of the gender continuum (even when they started out near the extremes). Strikingly, however, we observed a very different pattern — with chains instead converging near the Male extreme — when observers were shown an Angry face but then tested on a Happy face. This is exactly the pattern one would expect if Angry faces are perceived (and thus misremembered) as more Male than they actually were. (In contrast, when Angry faces are tested with Angry faces, this sort of bias effectively cancels out.) These results illustrate how prominent stereotypes have reflections in relatively low-level visual processing, during exceptionally simple tasks.

36.353 Short exposure duration reveals a smooth transition from priming to adaptation

Ka Lon Sou[1](ksou001@e.ntu.edu.sg), Hong Xu[1]; [1]Psychology, School of Social Sciences, Nanyang Technological University, Singapore

Adaptation studies showed that the longer the adaptation duration, the larger the face identity or expression aftereffect. However, the adaptation duration in these timecourse studies starts from 1s and onwards. How does short adaptation duration affect facial expression aftereffect? In the current study, we adapted the subjects to short adaptation durations (17, 34, 50, 100, and 1000ms) of happy or angry faces, and baseline (without adaptor), and examined their judgment on subsequently presented facial expression in a 2-alternative-forced-choice task. We also asked the subjects to report the emotion of the adapting faces at these adaption durations. We found that the facial expression aftereffect starts at 100 ms adaptation duration (Angry: $p = .04$, $d = 0.66$; Happy: $p = .04$, $d = 0.62$), and increases with adaptation duration at 1000ms (Angry: $p = .01$, $d = 0.89$; Happy: $p = .02$, $d = 0.73$). It therefore supports the previous findings that the longer the adaptation duration, the larger the adaptation aftereffect. Moreover, recognition of the adapting face is significantly correlated with the aftereffect, $r = .19$, $p =.03$. This suggests that awareness of the adapting stimulus modules adaptation aftereffect. However, what happened to the adaptation duration that is shorter than 100ms? Priming has been studied with short exposure of the prime. We investigated the reaction time patterns, a key indicator for priming. When the adaptation duration was short (17 - 50ms) and the adapting face was angry, there was a significant correlation between the awareness of the adapting faces and the reaction time towards angry test faces, $r = .33$, $p = .04$, such that the more invisible the adapting angry face was, the faster the participants could respond to an angry face. This supports previous studies showing stronger subliminal than supraliminal priming effect. Together, these findings suggest that there is a smooth transition between priming and adaptation in exposure time.

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36.354 Capacity limitations to extract the mean emotion from multiple facial expressions depend on emotion variance

Luyan Ji[1](Luyan.ji@ugent.be), Gilles Pourtois[1]; [1]Department of Experimental-Clinical and Health Psychology, Ghent University

We examined the processing capacity and the role of emotion variance in ensemble representation for multiple facial expressions shown concurrently. A standard set size manipulation was used, whereby the sets consisted of 4, 8, or 16 morphed faces each uniquely varying along a happy-angry continuum (Experiment 1) or a neutral-happy/angry continuum (Experiments 2 & 3). Across the three experiments, we reduced

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the amount of emotion variance in the sets to explore the boundaries of this process. Participants judged the perceived average emotion from each set on a continuous scale. We computed and compared objective and subjective difference scores, using the morph units and post-experiment ratings, respectively. Results of the subjective scores were more consistent than the objective ones across the first two experiments where the variance was relatively large, and revealed each time that increasing set size led to a poorer averaging ability, suggesting capacity limitations in establishing ensemble representations for multiple facial expressions. However, when the emotion variance in the sets was reduced in Experiment 3, both subjective and objective scores remained unaffected by set size, suggesting that the emotion averaging process was unlimited in these conditions. Collectively, these results suggest that extracting mean emotion from a set composed of multiple faces depends on both structural (attentional) and stimulus-related effects.

36.355 **Attention Modulates the Ensemble Coding of Facial Expressions** Haojiang YING[1](ying0017@e.ntu.edu.sg), Hong Xu[1]; [1]Psychology, School of Social Sciences, Nanyang Technological University

When we are encountered a crowd of faces in a short period of time, how do we process such large amount of information? Do we selectively process some of them (selective attention) or obtain a gist of all the faces (ensemble coding)? It has been shown that we implicitly average the emotions of the faces that we encounter through ensemble coding. However, does selective attention play a role in this ensemble coding? To answer this question, in the current study, participants (n = 11) were instructed to maintain fixation at the central cross and then report the average emotion of four faces that surround the fixation cross under three cueing conditions. In each trial, participant's attention was cued to 1) the happiest face, 2) the saddest face of the group, or 3) the fixation cross. Results showed that cueing to the happiest face (M = 7.67%, SEM = 2.75%; $t(10) = 2.78$, $p = .019$, Cohen's d = 0.84) and to the saddest face (M = -8.91%, SEM = 3.29%; $t(10) = -2.71$, $p = .022$, Cohen's d = 0.82) significantly biased the judgment of the ensemble representation toward the cued face's emotion. Also, there is a significant difference between these two conditions ($t(10) = 2.89$, $p = .016$, Cohen's d = 0.87). Our results suggest that attention modulates the ensemble coding of facial expressions. The neural mechanisms of ensemble coding are therefore influenced by attention related pathways.

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36.356 **Representing Facial Expressions in Visual Working Memory: A Novel Adaptation of the Continuous Response Paradigm** Catherine J Mondloch[1](cmondloch@brocku.ca), Abbie L Coy[1]; [1]Psychology Department, Brock University

Most studies investigating emotion perception have used dichotomous response measures whereby each response is either correct or incorrect. We used a novel continuous response paradigm to investigate the precision of visual working memory for expressions of sadness, anger, and fear and to investigate whether biases in errors (e.g., incorrectly perceiving angry faces as fearful rather than sad) are evident early in visual processing. We created an "emotion wheel" by morphing three anchor expressions (anger/sad/fear) in 4% steps. On each trial (n = 750), a target face (an anchor or any randomly selected morph) appeared for 500ms. After a 900ms delay, participants (n=29) located the target face on the emotion wheel (comprised of 75 faces representing continuous variation in emotion). We measured the magnitude (degrees between target and response) and direction (e.g., towards or away from particular emotions) of response error. The magnitude of response error varied with proximity of the target to an anchor expression (smaller for unambiguous [target contained >75% of one emotion, m = 47°] vs. ambiguous [target contained < 75% of either emotion, m = 60°] targets, $p < .001$) and across expressions (smaller for unambiguous angry compared to sad or fearful expressions, ps < .001; smaller for ambiguous angry/fear and fear/sad blends than angry/sad blends, ps < .01). The direction of response biases for ambiguous targets favored threat-related expressions. Participants were biased towards anger and fear when viewing anger/sad and fear/sad blends, ps < .05; no bias was observed for angry/fearful blends. Collectively, our findings suggest prioritization of both direct (angry) and indirect (fearful) threat, as opposed to merely negative (sad) faces. Our results have important implications for emotion theory and for understanding threat-related biases in emotion processing.

Acknowledgement: Social Sciences and Humanities Research Council of Canada

36.357 **The eyes react to emotional faces in the absence of awareness** Petra Vetter[1,2](petra.vetter@rhul.ac.uk), Stephanie Badde[2], Elizabeth A Phelps[2], Marisa Carrasco[2]; [1]Dept. of Psychology, Royal Holloway University of London, [2]Dept. of Psychology & Center for Neural Science, New York University

BACKGROUND. The ability to quickly respond to threat is a key skill for survival. Threat-related emotional information, such as an angry or fearful face, gains perceptual access preferentially over neutral information. However, it is unknown whether emotional information has to reach awareness to be processed further and guide actions. Eye movements can track visual information that we are unaware of perceiving (Spering & Carrasco, TINS 2016). Our goal was to investigate whether threat-related facial emotions trigger specific eye-movements in the absence of awareness. METHODS. We presented upright and inverted face images with different emotional expressions – neutral, angry, and fearful – randomly in one quadrant of a dichoptic display. The faces were rendered unaware using continuous flash suppression and viewer's eye movements were recorded during successful suppression as determined by objective measures of awareness (chance level for face localization and for emotion categorization) and subjective measures of awareness (visibility rating of 0). RESULTS. In the absence of awareness, gaze moved away from upright angry faces and moved towards upright fearful faces. No such effects on gaze were found for inverted emotional face images. Our results show that emotional face expressions are qualitatively processed, that is, processed beyond mere detection, in the absence of awareness. Moreover, unaware emotional face expressions trigger specific eye movements, depending on the emotion displayed: gaze aversion for angry faces and gaze attraction for fearful faces. We suggest that this unconscious emotion-specific guidance of eye movements may be mediated by differential fight, flight, or freeze responses via a subcortical pathway involving the amygdala, pulvinar, and superior colliculus. Our results exemplify the unconscious power of emotions on our actions.

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36.358 **Does the composite face illusion modulate breakthrough of eye-regions from CFS?** Katie L.H. Gray[1](k.l.h.gray@reading.ac.uk), Richard Cook[2]; [1]Psychology and Clinical Language Sciences, University of Reading, [2]Department of Psychological Sciences, Birkbeck, University of London

The presentation of a rapidly changing high-contrast mask to one eye renders visual stimuli presented to the other eye invisible for several seconds (so called continuous flash suppression; CFS). Some emotional expressions (i.e. fearful faces) 'break-through' CFS and thereby enter conscious awareness more quickly than other emotional expressions. Here, we ask whether break-through is determined by the subjective experience of the stimulus, or by its low-level visual properties. We took advantage of a visual illusion where the top half of one face appears to fuse perceptually with the bottom half of another, when aligned spatially and presented upright. Using the emotional version of the composite face illusion (CFI) in conjunction with CFS, we explored whether the presence of illusory emotion can direct processing resources. Unsuppressed emotional (happy, fearful, neutral) lower face halves were aligned with suppressed neutral upper face halves, and the time it took for the upper face halves to break through suppression was measured. Although the suppressed face halves were physically identical, we predicted that the illusory emotion induced by the CFI could lead to some stimuli emerging more quickly than others. First, we validated the CFI in our stimuli, showing that the neutral upper face halves were perceived as more fearful or happy in the presence of a fearful or happy lower face half, respectively. In the CFS task, across 32 observers, we found a large significant effect of inversion, whereby the upper face halves were responded to more quickly when the stimulus configuration was presented upright rather than inverted. There was also a small effect of emotion, which did

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not interact with inversion. We take this as evidence to suggest that the low-level properties of the unsuppressed face region likely impact on breakthrough time, but that the illusory perception of emotion does not direct processing resources.

36.360 **Labeling Emotion: Semantic Processing of Facial Expressions** Yi-Chen Kuo[1](alex830625@gmail.com), Chon-Wen Shyi[1,2], Ya-yun Chen[1]; [1]Department of Psychology and Center for Research in Cognitive Sciences, National Chung Cheng University, Chiayi, Taiwan, [2]Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University, Chiayi, Taiwan

Due to formidable diversity and nuanced variability, we suspect that not only perceptual processing of facial configurations but also labeling them with semantic codes are needed using facial expressions to convey emotion. Here we examined whether the image-to- label conversion (ILC) strategy is actively employed when participants compared facial expressions of different identities in four conditions. In the BaseFace condition, they were to match facial expressions from the same identity; in the BaseLabel condition, participants were to choose between a pair of affective labels that matches a previously displayed facial expression; in the FaceCue, they were to match two faces of different identities but exhibiting the same expression; finally, in the LabelCue, they were to choose a facial expression that matches a previously displayed affective label. The results of Experiment 1 showed that that the inferior performance of the FaceCue condition might be due to doing ILC twice in that condition, both when the face cue and when the face alternatives were displayed, which can be both time-consuming and error-prone. In Experiment 2, we manipulated the stimulus onset asynchrony (SOA) between cue and choice display to further explore the timing of ILC and the duration it might require. The results indicated that (a) with relatively short SOA (500 ms), participants may have adopted feature-based matching, which was time-consuming, (b) when SOA was increased 1,000 ms, they appeared to rely upon holistic processing of faces, yielding faster RTs, and finally (c) when SOA was further increased to 1,500 ms, participants appeared to adopt ILC strategy for converting both the face cue and test faces into corresponding affective code, and as a consequence, led to longer RTs. These interpretations were further tested and corroborated by the results of Experiment 3, where we used a block design for manipulation the duration of SOA.

36.361 **Negative facial expressions are seen as more intense when viewed in the evening** Paul E Moon[1](paul.e.moon@emory.edu), Elli B Recht[1], Hillary R Rodman[1]; [1]Department of Psychology, Emory University

Although substantial work has been done on diurnal fluctuations of visual attention and memory, much less is known about time-of-day influences on processing visual social stimuli, or how such influences interact with chronotype (preference for being active earlier or later in the day). Here, we examined how perception of facial expression intensity varies with chronotype, match between chronotype and time of testing, and time of testing per se (morning or evening). College students (51 female, 18 male) rated emotional intensity of black-and-white facial images of two individuals from the NimStim face set. Software was used to blend neutral expressions with sadness, happiness, anger, or surprise to create ten intensity steps for each emotion. Stimuli were presented on a monitor under standard fluorescent lighting with external light blocked from the room. Subjects were defined as either evening or non-evening chronotype based on scores on the Horne-Ostberg Morningness-Eveningness Questionnaire (MEQ) and sleep midpoint from self-reports of the previous night of sleep, and allowed to select a morning (7-10 AM) or evening (7-10 PM) session. Chronotype and match between chronotype and testing time did not significantly affect expressiveness ratings. However, exploratory analyses yielded a significant main effect of test-time for sad and angry faces (but not happiness or surprise) in the upper range of expressiveness. Evening testing produced higher ratings. Control analyses indicated that this relationship was not due to evening types and non-evening types selecting evening/ morning sessions, respectively. Thus, young adults appear to perceive strongly negative facial expressions as especially negative when viewed in the evening. The absence of a pure chronotype effect may reflect the small number of extreme morning types in our sample. The results underscore the potential importance of taking time of day into account in studies of visual facial emotion processing.

36.362 **I See What You Mean: The Influence of Alexithymia on the Processing of Nonverbal Cues** Pauline Pearson[1](p.pearson@uwinnipeg.ca), Lorna S Jakobson[2]; [1]Department of Psychology, University of Winnipeg, [2]Department of Psychology, University of Manitoba

Alexithymia is a personality trait characterized by difficulty describing feelings, difficulty interpreting feelings, and an externally focused thinking style. Individuals with alexithymic traits also have difficulties inferring what others are feeling and empathizing with them (i.e., affective mentalizing skills). The current study examined whether they also have difficulty interpreting a speaker's intended meaning, especially those communicated through nonverbal cues —a skill that requires cognitive mentalizing. A non-clinical sample (N=70) of university students was shown a series of short videos, selected from the Relational Inference in Social Communication database (Rothermich & Pell, 2015), which depicted speakers making literal or indirect statements to a conversational partner. In half of the videos, participants were given a verbal cue about the speaker's intent, whereas in the remaining videos only nonverbal cues (e.g., facial expressions, eye movements, gestures, and body language) were available to support participants' inferences. Alexithymia (Toronto Alexithymia Scale; TAS-20), empathic ability (Interpersonal Reactivity Index; IRI), verbal IQ were measured, along with accuracy and reaction time for identification of the speaker's intention. Verbal IQ and IRI Fantasy scores were important predictors of people's ability to discern speakers' intentions accurately when verbal context was available ($F(2,69) = 6.19$, $p = .003$). In the absence of verbal context, those who had difficulty describing their own feelings performed more accurately ($F(3,69) = 5.54$, $p = .002$), whereas those who had greater difficulty identifying their feelings needed more time to make their judgments ($F(2,69) = 3.48$, $p = .037$). We show that although individuals who have problems distinguishing their feelings from other inner states (i.e., atypical interoception) are not less accurate at interpreting nonverbal cues, they do need more time to interpret them. These findings support the view that interoception is fundamental to both affective and cognitive mentalizing.

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Spatial Vision: Textures and statistics

Sunday, May 20, 2:45 - 6:45 pm, Banyan Breezeway

36.363 **A Texture Representation Account of Ensemble Perception** Sasen S Cain[1](sasen@mit.edu), Matthew S. Cain[2,3]; [1]Department of Psychology, University of California San Diego, [2]Natick Soldier Research, Development, & Engineering Center, U.S. Army, [3]Center for Applied Brain & Cognitive Sciences, Tufts University

Can multiscale image statistics (Portilla & Simoncelli, 2000) explain ensemble perception phenomena better than feedforward object recognition? In the conventional view, objects' properties are rapidly measured and averaged to provide scene gist information (Alvarez, 2011), but this mechanism doesn't fit patterns of human performance. We showed (Cain, Dobkins, Vul, VSS 2016) that mean circle size judgments were systematically biased when comparing different numbers of items: participants selected the display with more items as larger, incurring robust point of subjective equality (PSE) shifts. Others have noted this perturbation (Chong & Treisman, 2005; Sweeny, et al., 2014), yet maintain the conventional view. We replicated the experiment and developed a computational model of how texture statistics could—without individuating or measuring objects—explain both the successes and failures of human ensemble perception. We trained linear support vector machines (SVMs) with three feature sets that reflect increasing amounts of image structure: pixel statistics (multiscale luminance properties, 16 features), marginal statistics (pixel statistics + autocorrelations, 421 features), full texture statistics (marginal statistics + crosscorrelations, 2456 features). The 48 easiest Equal set-size trials formed the training set; on each 2AFC trial, we computed the difference in these statistics between the two displays. Each SVM's classifications on the remaining 768 trials were used to fit its psychometric function. Compared to humans' PSE shifts, the pixel SVM's PSE shift was too extreme (a 2:1 ratio, as predicted), while both higher-order statistics (marginal and full) matched humans' PSE shifts. Because the marginal and full SVMs responded identically, the addi-

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tional crosscorrelation features are unnecessary for explaining human behavior on this task, while the autocorrelations of the marginal statistics are crucial. Our ideal observers successfully reproduce robust human biases on an ensemble mean task—without explicit object representation. This texture representation approach could be applied to arbitrary scene stimuli to more parsimoniously explain parallel preattentive processing.

36.364 **Co-circularity aftereffect in texture perception** Hiromi Sato[1,2](satou.hiromi@gmail.com), Frederick A. A. Kingdom[1], Isamu Motoyoshi[3]; [1]McGill Vision Research, Department of Ophthalmology, McGill University, [2]JSPS Research Fellow, [3]Department of Life Sciences, The University of Tokyo

It is well known that the human visual system has neural mechanisms sensitive to co-circularity among oriented edges, which play an important role in the detection of object contours. Here, we report a novel aftereffect in which the appearance of a texture is dramatically altered after adaptation to a texture composed of elements with co-circular structure. Following prolonged viewing of a texture made of pairs of adjacent Gabor elements arranged to form obtuse angle co-circular pairs, i.e. shallow curves, the subsequently viewed random texture appeared to be composed of acute angle pairs, i.e. V shapes. Conversely, following adaptation to a texture made of V shapes, subsequently viewed random textures appear to be composed of shallow curves. A possible explanation of this aftereffect is that mechanisms sensitive to co-circularity are organized in an opponent manner, with one pole sensitive to shallow curves the other V shapes. This notion was tested further in a non-adaptation 2AFC experiment in which co-circular and non-co-circular Gabor pairs were mixed within a single texture. Results revealed summation between pairs that fell on one side of the opponent continuum, and cancellation between pairs that fell on opposite sides of the continuum. These results support opponent interactions between mechanisms sensitive to pairwise co-circular texture features.

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36.365 **Estimating number from dot displays relies on a visual sense of number – not on size or spacing** Emily M Sanford[1](e-sanfor4@jhu.edu), Justin Halberda[1]; [1]Johns Hopkins University

People seem to be able to rapidly estimate number from brief visual displays. It remains a mystery how they accomplish this behavior, i.e., what visual information or algorithms they rely on. While some have suggested that number is a primary visual feature (akin to amount of redness), others have claimed that this ability relies on visual density or other non-numerical visual features. A recent computational model has been developed for assessing the extent to which observers rely on numerical and non-numerical visual features in behavioral tasks. Here we use Panamath, a method that has been used by over 60 publications to date, and apply a computational model to assess N=6,361 participants' reliance on visual signals of number, size and spacing when making numerical comparisons. We found that responses varied with numerical ratio, $t(6360) = 229.77$, $p < .001$. Judgments also varied with relative spacing, $t(6360) = 119.32$, $p < .001$, and to a lesser extent with relative size, $t(6360) = -4.69$, $p < .001$. Participants were more likely to judge a dot set as more numerous if the dots were smaller and more spread out. We also examined which of these features were most predictive of participants' numerical judgments. Participants relied more on relative spacing than relative size, $t(6360) = 115.75$, $p < .001$. Most importantly, participants relied more on numerical ratio than on either relative size, $t(6360) = 227.02$, $p < .001$, or relative spacing, $t(6360) = 223.88$, $p < .001$. Our results highlight the value of using computational models to determine the extent to which participants rely on visual numerical and non-numerical signals when making number judgements – and provide evidence that humans do have a visual sense of number that goes beyond visual size and spacing.

36.366 **Binocular integration of simultaneous density contrast** Hua-Chun Sun[1](hua-chun.sun@mail.mcgill.ca), Curtis L. Baker[1], Frederick A. A. Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, McGill University

Texture density, defined as the number of elements per unit visual area, is an important perceptual dimension that is typically studied in two-dimensions (2D) - however it is unclear how we represent texture density information in three-dimensions (3D). One study has suggested that density is represented as if projected onto a 2D plane, based on the finding that density perception is unaffected by the range of depth over which the elements are distributed (Bell, Manson, Edwards, & Meso, 2015). Here we explored the 3D properties of density coding using simultaneous density contrast (SDC), in which the perceived density of a texture region is altered by a surround of different density (Sun et al., 2016). We used a 2AFC staircase procedure in which human observers compared the perceived density of a test plus surround with a match having no surround. We first manipulated the stereo-disparity of the surround plane systematically from near to far relative to the center plane (Experiment 1), and from a small to a large range of random depths (Experiment 2). We found weaker SDC when the center and surround planes were separated in depth, and when the surround dots were distributed across a large depth range. However these binocular SDC effects were found only for dense not sparse surrounds. We also measured SDC with center and surround presented dichoptically, monoptically and binocularly (Experiment 3). Strong interocular transfer of SDC was found in the dichoptic condition, in line with previous evidence showing interocular transfer of density adaptation (Durgin, 2001). Our data suggest that binocular information influences texture density processing, challenging the previous view of a solely 2D representation of texture density.

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36.367 **The unitary percept of object orientation is achieved through conjoint, not separate processing of horizontal and vertical axes.** Lavinia Carmen Uscatescu[1](lavinia.carmen.u@gmail.com), Martin Kronbichler[1], Thomas FitzGerald[2], Dragan Rangelov[3]; [1]Salzburg University, [2]University of East Anglia, [3]Queensland University

Our environment abounds in objects of different orientations. When we want to interact with these objects, e.g. by grasping, we can do so provided we accurately perceive their orientation. The orientation of an object can be characterized along three independent spatial axes: x (or slant), y (or tilt), and z (or depth). How does the human brain achieve the percept of object orientation, is it by processing each axis separately, or by processing them conjointly? Also, do different (combinations of) monocular and binocular depth cues affect our perception of depth differently? To answer these questions, we designed a behavioral task in which participants were asked to reproduce the orientation of a target array by adjusting the tilt and slant of a test array. On each trial, random combinations of target orientations on both X and Y were generated. Error magnitudes for each trial and for each axis were recorded. Over the course of three behavioral experiments, we coupled this task with an incremental number of depth cues, such that: i) only texture gradients were available; ii) texture gradients were coupled with line vergeance; iii) texture gradients, line vergeance and binocular disparity were used together. Our results appear to indicate a differential coupling strength between X and Y orientation perception according to which depth cues are available. In a follow-up fMRI study using the same behavioral procedure and texture gradients only, we presented not only trials where X and Y orientations were generated together, but also trials where only one of these axes was manipulated. The neuroimaging data have been analyzed through both effective and functional approaches, to further specify the brain areas involved in object orientation perception, as well as their coupling.

36.368 **Different symmetries, different mechanisms** Ben J Jennings[1](ben.jennings@mcgill.ca), Frederick AA Kingdom[1]; [1]McGill Vision Research, Department of Ophthalmology, Montreal General Hospital, [2]McGill Vision Research, Department of Ophthalmology, Montreal General Hospital

We compared the detection of three different types of symmetry in a visual search paradigm: (i) mirror symmetry, i.e., reflection around a vertical axis, (ii) radial symmetry, i.e., rotations around a centre, and (iii) translational symmetry, i.e., horizontally shifted repetitions. Observers located a single patch containing symmetric dots among varying numbers of distractor patches containing random dots. We used a blocked present/absent protocol and recorded both search times and accuracy. Search times for mirror- and radial-symmetry increased significantly with the number of distractors, but with the translational patterns search slopes were close to zero. Fourier analysis revealed that, as with images of

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natural scenes, the structural information in both mirror- and radial-symmetric patterns is carried by the phase spectrum. For translational patterns on the other hand the structural information is carried by the amplitude spectrum, consistent with previous analyses of perfectly regular dot patterns. Further analysis revealed that while the mirror and radial patterns produced an approximately Gaussian shaped energy response profile as a function of spatial frequency, the translational pattern profiles contained a distinctive spike, whose magnitude corresponded to the number of repeating sectors. We hence propose distinct mechanisms for the detection of different types of symmetry. A mechanism that utilises phase information, i.e., the spatial relationships among the dots, used to detect the mirror- and radial-symmetric patterns. On the other hand a pre-attentive mechanism that utilises amplitude information, for example the pattern of energy across spatial frequency, is responsible for the detection of translational symmetry and explains why translational symmetry is a pop-out feature.

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36.369 **Contextual Effects of High Dynamic Range (HDR) Luminance on Orientation Discrimination** Chou Po Hung[1,2](chouhung8@gmail.com), Onyekachi O Odoemene[1,3], Andre V Harrison[4], Anthony J Walker[1,5], Min Wei[1,5], Anthony Ries[1], Barry D Vaughan[1]; [1]Human Research and Engineering Directorate (HRED), US Army Research Laboratory (ARL), [2]Dept. of Neuroscience, Georgetown University, [3]Oak Ridge Affiliated Universities (ORAU), [4]Computation and Information Sciences Directorate (CISD), US Army Research Laboratory (ARL), [5]DCS Corp

Contextual cues are known to affect orientation discrimination and brightness perception, but how these two modalities interact in real-world perception is poorly understood. Studies of brightness perception based on laboratory stimuli are typically at ~100:1 luminance contrast ratio ('standard dynamic range', SDR), but real-world scenes have contrast ratios up to 1,000,000:1, and recent reports suggest that, at contrast ratios over 1000:1 ('high dynamic range', HDR), luminance normalization expands the perceived shadings of gray at the mode of the luminance distribution (Allred et al 2012). We hypothesized that the contextual mechanisms of luminance normalization and feature processing interact at the earliest stage of visual cortical processing, in primary visual cortex. We are measuring EEG, eye tracking, and visual recognition behavior under a two-alternative forced choice (2AFC) task and under rapid serial visual presentation (RSVP, 0.5-2 Hz). In both tasks, a contrast mixture of two orthogonal Gabors appears as a central target, and the subject is instructed to indicate via keypress the orientation with the stronger contrast. The target is surrounded by a 5 x 5 grid of Gabor flankers, each on a separate luminance patch from an HDR luminance distribution. In a baseline condition with uniform flanker orientation and isoluminant patches, we reliably reproduced the classic 'pop-out' effect (Li 1999). We predict that, at HDR luminance, the contextual orientation effect is stronger for patches that are more similar to the target luminance. We also predict that this luminance dependence is stronger for HDR than for SDR luminance distributions. We predict that the ERPs will be consistent with the integration of orientation and luminance cues in visual cortex and that the RSVP task will reveal the spatial dependency of this contextual effect.

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36.370 **Modeling visual sensitivity to spatial correlations in gray-level textures** Jonathan Victor[1](jdvicto@med.cornell.edu), Lilah Evans[2], Mary M. Conte[1]; [1]Brain and Mind Res. Inst., Weill Cornell Medical College, [2]Howard University

Analysis of local image statistics underlies a wide range of basic visual processes, including segmentation and surface characterization. Visual textures are useful probes of the neural computations that are involved, as they enable isolation of individual image statistics and detailed study of their interactions. However, while image statistics have enormous variety, most studies focus either on image statistics defined by multiple gray levels but ignore spatial correlations, or statistics that focus on spatial correlations but ignore gray levels. Recently, we proposed a model that goes beyond these limitations. The model is completely constrained by previous measurements: the impact functions of Silva & Chubb (2014) to account for sensitivity to multiple gray levels without spatial correlation, and the quadratic form of Victor & Conte (2015) that accounts for sensitivity to binary textures with spatial correlations. In an out-of-sample test, we (VSS 2016) tested the model for textures that combine 3 gray levels and spatial correlations. Its predictions were in reasonable agreement with perceptual measurements. Here, we further test the model with spatial correlations involving up to 11 gray levels. We examined two kinds of spatial correlations: "stepped gradients," in which the contrast of adjacent checks tended to increase gradually or decrease abruptly in one direction, and "streaks," in which adjacent checks tended to have the same intensity. Subjects (N=3) performed a 4-AFC segmentation task, in which target and background were defined by these features. For stepped gradients, thresholds were markedly higher for 5 gray levels than either for 3 or 11 gray levels. For streaks, thresholds showed little dependence on the number of gray levels and were lower overall than for stepped gradients. These findings were predicted by the model. However, there was a small anisotropy in sensitivity to vertical gradients, suggesting gradient-sensitive mechanisms that the model has not captured.

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36.371 **Interaction between form and motion processing contributes to habituation to distortions of the natural visual world** Selam Wondimu Habtegiorgis[1](selam-wondimu.habtegiorgis@uni-tuebingen.de), Caroline Erlenwein[3], Katharina Rifai[1,2], Siegfried Wahl[1,2]; [1]Institute for Ophthalmic Research, Eberhard Karls University, Tübingen, Germany, [2]Carl Zeiss Vision International GmbH, Aalen, Germany, [3]Institute of Applied Optics, University of Suttgart

Spatial geometric distortions, such as image skew, recurrently occur in the visual world when using spectacles like progressive additional lenses. Image skew alters form information as well as motion direction statistics of the natural world. The visual system seems to compensate for these alterations during habituation to distoritons of spectacles. Here, we tested whether the interaction between form and motion cortical processing contributes to habituation to distortions of the natural visual world. A motion direction adaptation aftereffect (MAE), induced by distorted form and motion features of ecological stimuli, was psychophysically evaluated with a constant stimulus procedure in 10 observers. MAE was tested with two types of adapting stimuli; type 1: skewed dynamic natural image sequences (both form and motion features), type 2: skewed static natural images (only form feature). After exposure to either of the adapting stimuli, observers identified if the direction of coherently moving random dots was either diagonally up or diagonally down. The aftereffect was quantified by the point of subjective equality (PSE), i.e. the direction of the moving dots percieved as horizontal. After exposure to both types of the adapting stimuli, the PSE significantly shifted to the adapting skew direction, $p< 0.05$. The reported perceptual adjustment in motion perception after exposure to distortion induced alterations of form feature in static natural images reveals interaction between form and motion visual processing. Thus, cortical interactions in form-motion processing possibly partakes in the process of habituation to geometric distortions of the natural environment.

36.372 **Optimal binocular disparity estimation in the presence of natural depth variation** Arvind V Iyer[1](arvindiy@sas.upenn.edu), Johannes Burge[1]; [1]Department of Psychology, University of Pennsylvania

Reliable estimation of binocular disparity is fundamental to our ability to estimate the relative depth of objects in natural scenes. Classical laboratory stimuli are not representative of the stimuli that disparity-processing mechanisms encounter in natural scenes. Here, we examine the impact of natural disparity variation (arising from natural depth variation) on optimal disparity estimation. First, we obtained a database of calibrated natural stereo-images with precisely co-registered laser measurements of groundtruth distance at each pixel. Next, we developed a procedure for sampling binocular stereo-pairs from the dataset with arcsec precision and created a ground-truth labeled training set for a range of disparities (1deg/patch; 1000patch/disparity). Then, using Accuracy Maximization Analysis, we learned a small population of model neurons having linear receptive-fields (RFs) optimized for disparity estimation. The population responses were obtained by projecting the contrast-normalized stereo-pairs onto the RFs with multiplicative neural noise. These population

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responses optimally encode the disparity information in the natural stimuli, and also specify the optimal non-linear (quadratic) pooling rules for decoding disparity. Finally, we measured disparity estimation performance with an optimal Bayesian decoder. To isolate the effect of natural depth variation on estimation performance, we repeated the analyses with 'flat' stimuli i.e. stereo-pairs sampled from a single eye's image thus preserving natural luminance variation but excluding natural depth variation. For both natural and flat stimuli, the precision of disparity estimation decreases consistent with Weber's Law. Estimate precision is approximately tenfold lower for stimuli with natural depth variation than for flat stimuli. Natural stimuli vary in the amount of local depth variation they exhibit, which we quantify by a measure called disparity contrast. In future work, we will systematically study the effect of disparity contrast on population responses of the optimal encoders, and on overall estimation performance.

36.373 **Temporal Cues to Defocus in Emmetropia and Myopia** Michele Rucci[1,2](mrucci@bu.edu), Jonathan D Victor[3,4]; [1]Dept. of Brain & Cognitive Sciences, [2]Center for Visual Science, University of Rochester, [3]Feil Family Brain and Mind Research Institute, [4]Department of Neurology, Weill Cornell Medical College, New York

During development, the eye tunes its size to its optics so that distant objects are in focus, a state known as emmetropia. The visual signals entering the eye are generally considered to play an important role in this process, but the relevant features of the retinal image (e.g., blur magnitude) are unclear, as are the mechanisms by which these features are extracted. Here, recognizing that the retinal input is not merely an image but a spatiotemporal flow of luminance, we propose that temporal features generated by fixational eye movements (FEMs) are critical. FEMs occur incessantly in humans and other mammals, transforming the spatial scene into temporal modulations on the retina, thus acting as a key step for encoding fine-scale spatial information (review: Rucci & Poletti, Annual Reviews of Vision Sciences 2015). Specifically, (a) FEMs enhance—rather than degrade—high spatial frequency vision during natural post-saccadic fixation, an effect that appears to originate both from precisely-directed microsaccades and the temporal modulations given by ocular drift, and depends on the temporal resolution of retinal circuitry; (b) the luminance modulations resulting from FEMs counterbalance the spatial frequency distribution of the natural world, yielding a spatiotemporal input to the retina with equal temporal power across spatial frequencies; and (c) FEMs, both microsaccades and drift, are under a surprising degree of oculomotor control. Building upon these recent results, we propose that the space-time reformatting caused by FEMs also plays a role in emmetropization. The fixational redistribution of power on the retina suggests several ways in which FEMs could provide blur information, all grounded in the spatiotemporal remapping that they induce. We describe some of these possibilities and their implications for emmetropization. A direct consequence of our viewpoint is that abnormal oculomotor behavior may contribute to the development of myopia and hyperopia.

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36.374 **Ideal observer for detection of occluding targets in natural scenes in the fovea and periphery.** R Calen Walshe[1](calen.walshe@gmail.com), Stephen Sebastian[1], Wilson Geisler[1]; [1]Center for Perceptual System, The University of Texas at Austin

Nearly all biological visual systems have the ability to separate relevant signals from background clutter. The natural-signals hypothesis suggests that biological systems exploit regularities in the statistical structure of natural scenes to solve this problem. Here, we study optimal detection of target signals that occlude part of the natural backgrounds they are presented on. Occluding targets are the most common in natural vision, but most of the existing literature has focused on additive targets because they are easier to work with both mathematically and experimentally. We develop a Bayes optimal detector for occluding targets that is limited by only the approximate sampling density of the primate retina and the natural scene statistics after retinal sampling. The performance of the optimal model is then compared to data measured in a human psychophysical detection task. To represent the scene statistics used by the Bayes detector we first filter natural scene patches with and without the target by a modulation transfer function that approximates the optics of the human eye. Second, we simulate the output of RGCs by blurring and downsampling the optically filtered image to match the expected retinal response at a given eccentricity. Then, we decompose the information relevant for detection of occluding targets. Luminance, pattern and boundary signals are computed separately for each patch. The variances and covariances of the features are then measured for a large set of background conditions and retinal eccentricities. Finally, performance of the optimal detector is measured in a set of background and eccentricity conditions for which we have measured human psychophysical responses. Our results show that human performance is approximately proportional to optimal. We conclude that much of the variation in detecting occluding targets across the visual field arises from the statistical structure of natural scenes and the limitations of retinal sampling.

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Visual Search: Attention

Sunday, May 20, 2:45 - 6:45 pm, Pavilion

36.401 **Ignorance vs. laziness: Why do people use suboptimal attentional control strategies?** Jessica Irons[1](irons.39@osu.edu), Andrew Leber[1]; [1]Department of Psychology, The Ohio State University

Goal-directed control provides a flexible and powerful mechanism for biasing attention towards task-relevant features. However, the extent to which control benefits performance depends critically on how an individual chooses to wield it (e.g. whether one biases a target's color vs orientation). Recently we showed that people frequently use suboptimal strategies to control attention in visual search. We attributed this poor performance to an avoidance of the effort required to sustain optimal search. However, an alternative account is that observers are simply ignorant of the best strategy. Here we examined whether promoting information gain would increase optimal performance. We used the Adaptive Choice Visual Search task (Irons & Leber, 2016), which allows observers to freely choose between two targets, red and blue, on each trial. The relative utility of searching for each target varies periodically with changes in the ratio of red to blue distractors. Typically, individuals search for the optimal target on only 60% of trials. In Experiment 1, we previewed the search display colors prior to presenting the full display, providing additional time for observers to survey the display and determine the optimal target. Nevertheless, choice performance did not change, suggesting that individuals did not take advantage of the preview to improve their strategy. In Experiment 2, we used a more direct approach and explicitly told participants the strategy for choosing optimal targets. Now, participants who received this strategy information made significantly more optimal choices than those that did not, although performance remained well below fully optimal. Together the results suggest that the suboptimal attentional control strategies are partially due to ignorance of better alternatives. However, even explicit awareness of the optimal strategy does not guarantee full compliance, suggesting that other factors, such as effort avoidance, also contribute to suboptimal choice performance.

Acknowledgement: NSF BCS 1632296

36.402 **Mechanisms behind learned distractor suppression in visual search** Marian Sauter[1,2](sauter.marian@gmail.com), Heinrich R Liesefeld[1], Hermann J Müller[1,3]; [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 Psychological Sciences, Birkbeck College, University of London, London, UK

How do we suppress distracting objects? When we search through our environment, for example looking for our friend in a crowded intersection, our attention commonly gets captured by events or things that are irrelevant to the task (like flashing traffic lights or brightly colored billboards). Until recently, the mechanisms behind distractor suppression were poorly investigated. A recent investigation (Gaspelin & Luck; 2017) directly compared three possible mechanisms: global salience suppression (only the salience signal is down-modulated), first-order feature suppression (the distractor feature value gets suppressed directly) and second-order feature suppression (feature discontinuities, i.e. distractor

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feature dimensions, get suppressed). Their evidence speaks in favor of first-order feature suppression models, but their study was limited to the color dimension. We investigated learned distractor suppression using the probability cueing paradigm: In repetitive visual searches, we can learn to reduce distractor interference when distractors predictably appear in certain regions (Goschy et al., 2014). This has been termed the location probability effect (Geng & Behrmann, 2002). We thereby directly compared learned suppression in the frequent distractor region versus near-maximal interference in the rare distractor region. To address issues raised by the reproducibility crisis, our pioneer study incorporated 184 participants. The results showed (1) a consistent target-location effect (faster RTs for targets in the frequent distractor region than in the rare distractor region) for same-dimension distractors but not different-dimension distractors; ruling out first-order feature suppression as an explanation. In further studies, we revealed (2) that differential mechanisms of such learned suppression are prevalent even over 24 hours, (3) evidence for this suppression using event-related potentials and (4) most importantly: the results generalize to other dimensions. Overall, our investigations speak largely in favor of inclusive second-order feature suppression models (like the dimension-weighting account), while not denying an element of first-order feature suppression.

Acknowledgement: Deutsche Forschungsgemeinschaft Grant MU 773/17-1

36.403 **Stronger top-down control due to preview visual search produces distractor suppression** Kenji Yamauchi[1](kjyamci601@gmail.com), Jun Kawahara[1]; [1]Hokkaido University, Department of Psychology

The presence of a salient but task-irrelevant item (singleton distractor) causes attentional capture, increasing the time required to detect a target during visual search. However, the literature shows that observers can overcome attentional capture via top-down controls based on attentional set. Specifically, when observers are required to search for a shape among nontarget shapes, the color singleton distractor has negligible impact and may even be advantageous for target detection. The present study examined a factor that causes this difference in search performance. Here, we hypothesized that whether a singleton distractor can be ignored or can even facilitate the search depends on the strength of top-down control. We predicted that stronger top-down control would yield active suppression of a singleton distractor as indexed by faster reaction times in the presence of the distractor. To manipulate the strength of top-down control, we introduced two types of search tasks, i.e., simultaneous and preview search tasks. The former consisted of a single display where all the stimuli were presented simultaneously, and the latter consisted of a preview display containing a subset of distractors followed by an additional display containing the remaining distractors and a target. The singleton distractor, if any, appeared in the additional display. We reasoned that observers would form a stronger attentional set during the preview display. The results revealed that reaction times were unaffected by the presence of a singleton distractor in the simultaneous search task. Importantly, the reaction times for the singleton distractor condition were faster than those for the no-singleton condition in the preview search task. These findings suggest that a singleton is actively suppressed by stronger top-down control due to the maintenance of preview search templates, resulting in more efficient search performance. An ordinary simultaneous search may not induce such active suppression

36.404 **Not Worth the Effort: Distributed displays and larger set sizes encourage efficient deployment of attention in visual search** Stephen C Walenchok[1](swalench@asu.edu), Stephen D Goldinger[1]; [1]Arizona State University

Rajsic, Wilson, & Pratt (2015; 2017) recently discovered a visual form of "confirmation bias" wherein people are biased to seek cued objects in visual search, even when this strategy is inefficient. Participants searched for a target letter in simple circular displays of colored letters of varying proportions. Critically, only one color was initially cued (e.g., "Press Z if the p is green, otherwise press M."), and all letters occurred in either the cued or in an uncued color. The ostensibly most efficient strategy was to restrict search to the minority color (e.g., green if 25% of letters were green; red if 25% were red) and use inference where necessary, obviating the need to actually inspect the target if it did not occur in the minority color, since a target was present in every trial. People rarely adopted this strategy, and prioritized inspections of cue-colored objects. However, when Rajsic et al. (2017) increased the cost of each inspection (e.g., with occluded, gaze-contingent letters), people adopted the efficient strategy. In the current paradigm, we increased the cost of inspections by presenting (1) randomly scattered "traditional" visual search displays and (2) increasing the set size. We also investigated whether varying the prevalence of cue-colored targets would encourage a more efficient strategy. We observed typical prevalence effects in search accuracy. However, search RTs suggested that people adopted a more efficient search strategy, especially as set size increased. These results suggest that while the "default" strategy of simply searching for what is most cognitively available is typically efficient, increasing the cost of inspections encourages more careful and deliberate deployment of attention.

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36.405 **A secondary task leads to poorer selection of attentional control strategies** Heather A Hansen[1](hansen.508@osu.edu), Jessica L Irons[1], Andrew B Leber[1]; [1]Department of Psychology, The Ohio State University

There are many strategies we can use to control attention when approaching a visual search task. For example, when searching for your vehicle in a parking lot, you may choose to bias your attention toward particular features of your vehicle, such as its color or size, to aid in your search. However, the most optimal strategy depends on properties of the environment, requiring necessary updates when searching through different environments. Thus, we have proposed that in order to search most optimally, individuals must engage a monitoring mechanism to assess their environment and determine the optimal control settings. In the present experiment, we examined whether the use of an optimal strategy can be disrupted by a secondary task that occurs at the start of the trial, when the monitoring mechanism would be most engaged. We used a visual search task where individuals are presented a search display composed of subsets of colored squares in which they can freely search for either of two targets – red or blue – on every trial (Adaptive Choice Visual Search, Irons & Leber, 2016). In each display, the number of items in the red and blue subsets differed such that one color contained twice as many items as the other, with the larger and smaller subset colors alternating periodically; the optimal strategy would be to search for the target in the smaller color subset. On some blocks, participants also completed the secondary task, a central line-length judgment, immediately before searching for a target. We found that participants were significantly less likely to search optimally under these conditions than when completing the search task by itself. Insofar as the secondary task disrupts an individual's ability to engage in monitoring, these results support the need for such a mechanism in the optimal choice of attentional control settings.

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36.406 **Understanding Visual Search and Foraging in Cognitive Development** Beatriz Gil-Gómez de Liaño[1](bgil.gomezdelianno@uam.es), María Quirós-Godoy[1], Elena Pérez-Hernández[1], Matthew S Cain[2,3], Jeremy M Wolfe[3]; [1]Universidad Autónoma de Madrid, [2]U.S. Army, Natick Soldier Research & Development Center, [3]Harvard Medical School-Brigham & Women's Hospital

How does visual search behavior change during development? We tested children using a standard visual search task (as has been done before e.g. Hommel et al., 2004) as well as a novel "Hybrid Foraging" task. In Hybrid Foraging, observers collect multiple instances of multiple types of target. For example, observers might pick all the blue and green squares in a display containing red, yellow, blue, and green squares (c.f. Kristjánsson et al., 2014). Hybrid foraging would seem to involve a richer set of attentional and executive functions than does a standard search task, and it has never been tested in children. 76 children, ages 6 to 10 were tested. All showed typical development as measured by several questionnaires/tests (BRIEF, CPT, BASC & RIST). Children ran a "Pirate-Treasure" Conjunction search, as well as two hybrid foraging "Hunting" tasks: Feature foraging (blue & green squares, among red and yellow distractors) and Conjunction foraging (green circles & blue squares among blue circles and green squares). Results show that RT decreases as a function of age for search and foraging tasks ($p < .001$). As usual, target absent RT x setsize slopes are steeper than target present ($p < .001$). Interestingly, the ratio of absent to present slopes seems to be larger in younger children

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(p=.02). This suggests that children may have different search termination rules. In the Hybrid foraging, it is interesting to ask about 'runs' of target selections. Do observers tend to pick the same target repeatedly or do they switch randomly between target types? The RT cost for switching to a new target is greater for younger observers, especially for the Conjunction task (p=.02). Moreover, younger children had a greater proportion of run trials (p=.009). Both VS and the new hybrid foraging paradigm appear to be useful tools for investigating the development of executive functions.

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36.407 **Feature integration across the dorsal and ventral streams in childhood** Andrew Lynn[1](andrew_lynn@brown.edu), Elena K Festa[1], William C Heindel[1], Dima Amso[1]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University

Introduction. Previous work shows a decline in selective attention but intact feature integration in healthy elderly adults using a novel visual search paradigm that manipulates the demands on dorsal-ventral visual stream interactions (Heindel, Festa et al., 2009). However, the relationship between selective attention and feature integration has not been examined in childhood, during which time selective attention typically improves. Here we ask whether feature integration demands disrupt children's visual search performance, and whether this demand increase is modulated by selective attention efficiency. Methods. Children (N=42; 5-9 years) searched for a vertically moving target among vertically and horizontally moving distractors. We manipulated both target feature and set size. Targets were either black (motion-luminance condition) or red (motion-color condition) and distractors were either black and white, or red and green, respectively. Targets were presented among either two or four distractors. The motion-luminance and motion-color conditions placed minimal and maximal demands on cross-cortical interactions, respectively. Feature salience and search demands were matched across conditions. Thus, reaction time differences between feature conditions must be attributed to integration demands, while set size differences between conditions must be attributed to selective attention. Results. Preliminary results show that children were slower to find targets as set size increased [$F(2,54)=198.20$, $p< .001$]. While search time increased as set size increased in both feature conditions, search times did not differ between feature conditions when no distractors were present [$F(1,41)=0.192$, $p=.66$]. However, children were faster to detect luminance targets relative to color targets when either two [$F(1,40)=4.376$, $p=.04$] or four [$F(1,40)=3.282$, $p=.08$] distractors were present [feature by set size interaction: $F(2,54)=3.682$, $p=.03$]. Conclusion. Slower visual search on motion-color compared to motion-luminance trials suggests that cross-cortical feature integration may not fully develop until later childhood or early adolescence. Moreover, in childhood, greater feature integration demands may also increase attentional demands.

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36.408 **Individual Differences in Visual Search and Foraging in children** María Quirós-Godoy[1](maria.quirosgodoy@uam.es), Elena Pérez-Hernández[1], Matthew S Cain[2], Jeremy M Wolfe[3], Beatriz Gil-Gómez de Liaño[1]; [1]Universidad Autónoma de Madrid, [2]U.S. Army, Natick Soldier Research & Development Center, [3]Harvard Medical School-Brigham & Women's Hospital

There is empirical evidence showing a relationship between attentional performance and individual differences such as Working Memory (WM) capacity or emotional problems in children (Blanken et al., 2017). But, how do individual differences mediate selective attention in Visual Search (VS) tasks in children? To answer this question, we tested 88 children using a standard VS task (e.g. Hommel et al., 2004) and a Hybrid Foraging search task, where children had to look for two targets appearing more than once among several distractors, in Feature (blue & green squares, among red and yellow distractors) and Conjunction (green circles & blue squares among blue circles and green squares) conditions. To measure individual differences we ran several questionnaires/tests: BRIEF for Executive Functions, CPT for attentional problems, BASC for behavioral and/or emotional problems (BASC), and Intelligence Quotient (RIST). For the VS, results show differences in WM capacity: Children with clinical WM symptoms have steeper RT x Setsize slopes when the target is absent than children in normal range (p=.03), or children with higher WM capacity (p=.01). In the Hybrid Foraging task, the differences show up for the Conjunction condition where clinical WM children spend more time looking for each target compared to those with higher WM capacity (p=.026). This result is only significant when the target is a switch (change of target, p=.024) but not when it is a run (a repetition target found). Other interesting relationships were found for RT in the Foraging Feature with Depression (r= .287, p=.009), Adaptability (r=-.302, p=.006), Social Abilities (r=-.272, p=.015) and Leadership (r=-.224, p=.044). For the Foraging Conjunction RT correlated with initiative (r=-.276, p=.011), and Cognitive Regulation too (r=-.274, p=.013). Hybrid Foraging tasks seem to be a potential tool to explore attentional processes in children sensitive to individual differences.

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36.409 **Visual search slopes are not caused by increased distractor numbers: Insights from visual foraging** Tomas Kristjansson[1](tok1@hi.is), Árni Kristjánsson[1]; [1]Icelandic Vision Lab, School of Health Sciences, University of Iceland

According to two-stage models of visual search, search slopes during conjunction search reflect increased distractor numbers – and that conjunction search involves serial, self-terminating search where distractor items are checked off one by one. There is however an inherent problem with measuring set-size effects with the single target search. When distractors are added, both absolute set-size (the number of stimuli on the screen) and the relative set-size (the target vs distractor ratio) increase. Do search slopes reflect increasing absolute set-set size or decreasing relative set-size? We addressed this question using a visual foraging task, where observers tap multiple target items among distractors. But this paradigm also entails a challenge, since as targets are selected, they disappear, changing both absolute and relative set-size. We therefore tested three foraging conditions, a 'classic' condition, where targets disappeared when tapped, a 'replace' condition where targets turned into distractors when tapped, keeping absolute set-size constant throughout the trial and finally a 'disappear' condition where a random distractor disappeared along with the target tapped, keeping relative set-size constant. We tested these three conditions during both feature and conjunction foraging. When absolute set-size was kept constant, but relative set-size changed throughout the trial (replace condition), switch-costs were higher, the RTs for the final foraging target slower and generally all indicators of task difficulty showed that manipulating relative set-size had a larger effect on foraging performance than manipulating absolute set-size. Furthermore, our previous results have shown that the final-target RT's during foraging tasks replicate the search slopes seen in single target search tasks. Here, we see this same traditional pattern in the replace condition, but not in the disappear condition, suggesting that absolute set-size is indeed not responsible for the traditional set-size effects seen in single target conjunction search.

Acknowledgement: Icelandic Research Fund

36.410 **The Flux Capacitor Account: A New Account of Multiple Target Visual Search Errors** Stephen Adamo[1](sadamo13@gmail.com), Joseph C Nah[1], Andrew J Collegio[1], Paul S Scotti[2], Sarah Shomstein[1]; [1]The George Washington University, [2]The Ohio State University

Multiple-target visual searches, where more than one target can be present in a search array, are subject to subsequent search miss (SSM) errors. SSM errors are characterized by a decrease in second target detection after successful detection of a first target. While SSM errors have been studied within radiology for over 50 years, their underlying cause remains elusive. Previous research suggested that SSM errors are driven, in part, by target similarity, such that a second target is more likely to be missed if it is a different color or category from a previously found target (e.g., Biggs et al., 2015). Here, we directly and systematically investigate the extent to which SSM errors are influenced by perceptual similarity in identity, rotation, and color. In Experiment 1, four search items were independently rotated either 0°, 90°, 180°, or 270° and presented for 400ms or 1000ms, centered around a fixation point. Second target accuracy improved when both targets shared identity (i.e., both Ts/Ls) and rotation, compared to when both targets were either different identities (i.e., a T and an L) or

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different rotations (e.g., two T's of different rotations). Experiment 2 and Experiment 3 retained the design of Experiment 1 with a key difference: similarity was parametrically manipulated with 0° (i.e., identical), 10°, 20°, or 80° difference between targets in color (color-wheel, Experiment 2) or rotation (Experiment 3). Consistent with our earlier finding, the results demonstrated that as target similarity increases, SSM errors decrease systematically. These results will be discussed within the framework of a new "Flux Capacitor" account of SSM errors. This account suggests that a first target acts as an attentional template for subsequent targets making it more likely to detect targets that are perceptually similar and more likely to miss targets that are perceptually dissimilar to a first target.

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36.411 **What Can Intraindividual Variability Teach Us About Dual-Target Visual Search?** Robert Sall[1](rjsall@ncsu.edu), Emily Lefebvre[1], Shevaun D Neupert[1], Jing Feng[1]; [1]Department of Psychology, North Carolina State University

Tasks that require visual searches for multiple targets are known to present unique problems from those involving just one target. The Satisfaction of Search (SOS; also called Subsequent Search Misses) paradigm describes one such example of this, whereby searchers are less likely to locate a second target after the first has been identified. While the original hypothesis involved observers prematurely terminating their search once they had been "satisfied" by the detection of one target, recent work has led to a myriad of cognitive and perceptual limitations involved in this unique pattern of flawed visual search. One particularly compelling theory describes a depletion of cognitive resources that prevents searchers from finding a second target. The current analysis uses multilevel modeling to expand this theory of resource depletion in SOS. This analysis began by calculating an intraclass correlation coefficient to determine how much variance in these dual-target errors existed within-participants across timepoints of the experiment (i.e., level 1), and between-participants (i.e., level 2). This unconditional model revealed that the overwhelming majority of variance existed at level 1. The next model used time as a level 1 predictor to demonstrate a significant increase in SOS-errors as the experiment progressed. Furthermore, non-significant random effects (i.e., □11) for the slope in this model indicated consistent variance across participants in this performance decrement. Previous descriptions of resource depletion in this paradigm have revolved around more acute examples of cognitive resources (e.g., working memory), that are studied in a single trial. However, this model suggests limitations of a chronic cognitive mechanism that depletes over many trials.

36.412 **Abolition of Search Asymmetry** Ronald A Rensink[1](rensink@psych.ubc.ca), Sogol Ghattan-Kashani[1], Emily S Cramer[1]; [1]Departments of Computer Science and Psychology, University of British Columbia

Although visual search has been studied for years, some aspects remain poorly understood. For example, Westerners show a search asymmetry for line length: search for long lines among short is faster than for short among long. In contrast, Asians given the same task show no asymmetry (Ueda et al., 2017). And asymmetry for long-term Asian immigrants in a Western country depends on the language in which task instructions are given (Cramer et al., 2016). To examine how this asymmetry depends on preceding task, 16 Westerners were given a pre-task before visual search. They were shown a sequence of 14 images of real-world scenes, and asked to count the number of animals in the series. In the subsequent search for line length (5 blocks of 30 trials per block for each target type), average target-present slope was 42.5 ms/item for long targets and 53.9 ms/item for short (t-test: $p = 0.024$); average ratio of short- to long-target slopes was 1.39 (z-test: $p = 0.002$). Search was therefore asymmetric, consistent with that of Westerners tested on similar stimuli (e.g., Cramer et al., 2016). Another 16 Westerners were then shown exactly the same sequence of scenes, but with a different pre-task: rate (on a scale of 1-7) how much they liked each one. Average target-present slope was now 47.7 ms/item for long targets and 44.0 ms/item for short (t-test: $p = 0.45$); average slope ratio was 0.99 (z-test: $p = 0.45$). Search asymmetry was therefore abolished, with behavior similar to that of Asians tested on the same stimuli (Ueda et al., 2017). These results suggest that attention in visual search has at least two modes, with selection of mode affected by the preceding task. Different deployment of these modes may also explain some of the differences found in observers from different cultures.

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36.413 **Distractor specificity leads to contextual cueing effects in target-absent search condition** Jeunghwan Choi[1](abcdef0518@naver.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

People search targets more efficiently in repeated configurations than in novel configurations (contextual cueing; Chun & Jiang, 1998). Most studies suggest that target-distractor associations could guide attention to the target location. However, studies have found conflicting results on whether repeated configurations without a target could produce contextual cueing effects (Beesley et al., 2015) or not (Kunar & Wolfe, 2011). We outlined three major differences between the two studies that might influence the formation of distractor-distractor associations, and investigated which factor produced contextual cueing effects in the target-absent condition. First, the number of distractors in each configuration may influence the formation of distractor-distractor associations by changing the average inter-distractor distance and the number of possible distractor-distractor associations. Second, the number of repeated configurations that people could learn simultaneously may be limited. Finally, distractor specificity in terms of visual features may increase the strength of distractor-distractor associations. In Experiment 1, we manipulated the number of distractors within participants and the number of repeated configurations between participants. Participants searched for a T shape (target) among L shapes (distractors). We found contextual cueing effects only in the target-present condition regardless of the number of distractors and repeated configurations. In Experiment 2, we increased distractor specificity by adding a second, task-irrelevant feature (i.e. color) to the target and distractors, thereby rendering distractor-distractor associations more specific. By increasing the distractor specificity, we revealed contextual cueing effects in both target-present and target-absent conditions. These results suggest that distractors with enough feature specificity can be associated with other distractors and contribute to the contextual cueing effect. Meanwhile, the number of distractors and the number of repeated configurations do not play a key role in building distractor-distractor associations.

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36.414 **Task relevance affects the context-dependency of implicit learning** Injae Hong[1,2](honginjae113@kbri.re.kr), Su Keun Jeong[2], Min-Shik Kim[1]; [1]Department of Psychology, Yonsei University, [2]Department of Structure & Function of Neural Network, Korea Brain Research Institute

Recent studies have revealed that a spatial bias emerges toward a location where a target appears with high probability. However, it is not clear whether the spatial bias can distinguishably emerge when different context contains different probabilistic information. In the current study, participants searched for a target among multiple distractors. The context (i.e., the color of stimuli) predicted which quadrant is more likely to contain a target. For example, a black target appeared more frequently in one quadrant of the search display, and a white target appeared more frequently in another quadrant. If probability learning is context-specific, a spatial bias to different quadrants would emerge depending on a given context. In contrast, an equal spatial bias to two quadrants would emerge regardless of contexts, if probability learning is context-independent. In Experiment 1, when a search display contained only one context (either black or white stimuli), attention was equally biased to both target-frequent quadrants regardless of the context, showing context-independent spatial bias. This result was not due to lack of time to process context information (Experiment 2). However, context information was not critical in Experiments 1 and 2, because each search display only contained a single context. In Experiment 3, a search display contained both black and white stimuli and participants were pre-cued which color context they should use. Results showed that a significant context-specific spatial

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bias emerged as context became task-relevant. Context-specific spatial bias could have been the result of increased task difficulty as the set size doubled. However, context-specific spatial bias was still not found when search became difficult by modulating target-distractor similarity, suggesting that task relevance, not task difficulty, influences context-specific spatial bias. These results demonstrate that statistical knowledge can be distinguishably learned for different contexts, when the contexts are relevant to the task.

Acknowledgement: 17-BR-02, NRF-2015R1A2A2A04006136

36.415 **When does implicitly-learned spatial context bias attention?** Yoolim Hong[1](hong.503@osu.edu), Andrew B. Leber[1]; [1]Department of Psychology, The Ohio State University

Familiar spatial contexts are typical in everyday tasks, and we use knowledge of such regularities to promote optimal behavior. However, in the real world, we face a dilemma between exploiting learned context information to maximize performance and exploring novel information to discover new, potentially informative regularities. Here, we investigate this tradeoff. Participants searched for a T among Ls in displays containing a vertical borderline, dividing displays into two sides. Each side contained distinct spatial arrangements of items. On each trial, we presented one of 16 invariant arrangements (presented once per block) on one side and a random arrangement on the other side. Additionally, we manipulated the task-relevance of the repeated arrangements during a Training Phase, across three groups, to see whether people exploit regularities when it is beneficial or not: in the Target-Inside group, a target always appeared at one location inside the repeated arrangement and never appeared in the random arrangement. In contrast, a target was always presented outside the repeated arrangement in the Target-Outside group. Finally, a target appeared equally often inside or outside the repeated arrangements in the Target-Random group. During the Test Phase, to determine whether attention was biased to repeated vs. random display sides, a target was presented equally often inside or outside of the repeated arrangement. Training results revealed an early but short-lived acquisition and expression of context learning, demonstrating biasing attention towards regularities is transient when it cannot benefit behavior. Test results showed faster RTs for targets appearing outside compared to inside repeated arrangements for the target-outside group but no inside/outside RT difference in the target-inside/random groups. The failure of the target-inside group to bias toward the regularity – though it would benefit behavior – confirms a drive to explore novel/random stimuli. These results support an exploration/exploitation tradeoff in spatial context learning.

Acknowledgement: NSF BCS-1632296

36.416 **How do 25,000+ visual searches change the visual system?** Igor S. Utochkin[1](isutochkin@inbox.ru), Jeremy M. Wolfe[2]; [1]National Research University Higher School of Economics, Russia, [2]Visual Attention Lab, Brigham & Women's Hospital & Harvard Medical School, United States

Inefficient visual searches are those where reaction time (RT) increases substantial as the number of items in the visual display (set size) increases. After extended practice, an inefficient search can become efficient (little RT increase with set size). What changes occur in the visual system during search practice? Treisman (2006) suggested that observers might "grow" new feature detectors, capable of preattentively registering trained complex targets. To test this, we trained two groups of five participants to search for an artificially created complex feature: "openness to the right". For one group, stimuli were curved "amoebas"; for the other, straight line "trees". Participants were trained for 16 days (25,600 trials per participant in total). A control group was trained to search for color-color conjunctions. To estimate specific effects of training, we pre-tested and post-tested, participants on all three tasks ("amoebas", "trees", and color-color conjunctions). We measured search efficiency and search asymmetry. We also measured transfer of training from "amoebas" to "trees" and vice versa to estimate the generality or specificity of the "feature". Critically, the presence of a new feature was assessed with selective adaptation. It should be possible to adapt a feature (Treisman, 2006). We found a general effect of training on search efficiency (post-test RT slopes were 55% of pre-test). We also found strong asymmetries specific for the training tasks (slopes decreased 6-7 times for trained targets vs. 1.04-1.19 times for trained distractors). Transfer from amoeba to tree or tree to amoeba was weak (~13% slope benefit). No selective adaptation was found. Our results do not support formation of a general feature detector with practice. It is more likely that, with practice, participants learned more effective top-down guidance by existing features. Seen as a form of perceptual learning, our results represent a different form of a failure of far transfer.

Acknowledgement: Basic Research Program at HSE

36.417 **Active response inhibition impairs subsequent search efficiency** Yoojeong Choo [1](yoojeong.joo@yonsei.ac.kr), Do-Joon Yi[2]; [1]Department of Psychology, Yonsei University, [2]Department of Psychology, Yonsei University

The primary challenge for theories of cognitive control is to explain how the cognitive system reliably distinguishes relevant from irrelevant information. Such selection processes must be achieved through multiple stages ranging from the blocking of unnecessary sensory inputs to the suppression of inappropriate actions. An intriguing question, therefore, might be how different stages of selection processes interact with each other. Specifically, the current study asked if response inhibition shares common resources with perceptual selection. In each trial of two experiments, participants performed a go/no-go task and a visual search in a row. In Experiment 1, participants either pressed a button or withheld a response depending on a cue color. In a visual search task, they reported a direction of rotated T among Ls. Overall search RTs were slower after no-go responses than go responses. However, response inhibition did not affect search efficiency, which was indexed by the slope of a linear function relating RTs and search set size (no interaction between set size and response inhibition). Such absence of interaction might result from the lack of active inhibition; an automatic component of response inhibition associated with a no-go color cue might be dominant in our experiment (Verbruggen and Logan, 2008). To reduce the involvement of automatic response inhibition, Experiment 2 employed a category cue (indoor or outdoor scenes) for no-go and go responses. The automatic retrieval of response inhibition should be minimized because scenes were never repeated across trials. As results, search efficiency was significantly impaired after no-go responses. In Experiment 3, we extended our findings using a stop signal paradigm. Again, search efficiency was impaired after the stop responses compared to the go responses. The current findings indicate that active cancellation of planned action interferes with concurrent perceptual processes, suggesting that two processes might share cognitive resources.

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36.418 **The influence of temporal structure on visual search: How prediction shapes top-down and bottom-up attention** Danlei Chen[1](chen.danl@husky.neu.edu), J. Benjamin Hutchinson[1]; [1]Department of Psychology, Northeastern University

Our past experience as reflected by learning and memory can impact where, and to what, we choose to allocate attention. At the same time, much past work in visual attention has focused on the influence of bottom-up (e.g., stimulus salience) and specific top-down factors (e.g., task goals) while attempting to minimize the role of memory (e.g., avoiding stimulus repetition and randomizing trial sequences). Here, we set out to instead characterize how prior experience influences attention by introducing repeating, non-random trial structure into a visual search task. Specifically, observers viewed a series of arrays of shapes and were required to indicate the direction of a target (T-shaped) among distractors (L-shaped). Unbeknownst to the observers, all trials were drawn from eight pairs of stimulus arrays wherein the second array of each pair was always preceded by the first array, while the sequence of pairs was kept random. Thus, all arrays were equated in terms of their absolute memory status (repetition) and differed solely in their predictability. Further, half of the arrays contained a color singleton distractor. This allowed examination of the influence of predictability (i.e., search performance on the second array in a pair versus the first) on visual search with and without bottom-up capture. Interestingly, it was found that predictability facilitated search (faster reaction times), but only in instances where there was not a singleton distractor. These findings indicate associative memory can inform the deployment of spatial attention, but that the predictions based on these memories might not overcome certain forms of bottom-up capture. Additionally, only one of 33 observers reported being aware of the pair structure, further suggesting that such prediction is implicit in nature. Overall, this work highlights how past experience, with or without our conscious awareness, can meaningfully influence our attention in the present in a systematic manner.

Visual Search: Real world

Sunday, May 20, 2:45 - 6:45 pm, Pavilion

36.419 **Exploring the Effect of Task Complexity, Presentation, and Input Device on the Near-Hands Advantage** Ronald Andringa[1](andringa@psy.fsu.edu), Nelson A Roque[1], Walter R Boot[1]; [1]Psychology,College of Arts and Sciences, Florida State University

Previously presented research examined whether hand-proximity might benefit a complex real-world search task, TSA baggage screening. A near-hands advantage was not observed and follow-up work is presented exploring why this effect might have been absent. First, a lack of effect might have been related to the complexity of the search task compared to the more abstract and simple tasks used previously. Second, our TSA experiments had participants in the near-hands condition respond by using touchscreen buttons on a tablet rather than pushing buttons attached to the side of a computer monitor, a more typical response mode and grip posture. In a new experiment, participants were asked to complete a simpler change detection task similar to Tseng and Bridgeman (2011) but on a tablet computer, using postures and responses identical to our previous baggage screening experiments. Unlike Tseng and Bridgeman (2011), no near-hand advantage was observed with respect to change detection accuracy (hands-near vs. away, $F(1, 50) = .37$, $p= .54$). One possibility is that the grip posture associated with holding a tablet and using thumbs to push touchscreen buttons is not conducive to producing a near-hands advantage. A second experiment directly tested this hypothesis with a direct replication of Tseng and Bridgeman (2011) in which participants responded to stimuli presented on a CRT monitor using buttons attached to the side of the display. Still, no near-hands advantage was observed ($F(1,47) =.047$, $p = .83$). In general, our results point to the idea that the near-hands advantage may be very sensitive to small differences in procedure, which may have important implications for harnessing the near-hands advantage to produce better performance outside of the laboratory.

36.420 **How optimal strategies evolve in memory-guided visual search: evidence from eye movement patterns.** Alicia Weisener[1](alicia.weisener@gmail.com), Roger Johansson[1]; [1]Department of Psychology, Lund University

In everyday life, we search for visual objects in complex environments and often encounter a similar search problem over multiple times. Previous research has shown that repeated exposure to the same scene increases search efficiency, yet little is known about the role of eye-movements underlying memory-guided search. In the present study, we investigated how eye-movement patterns evolve over repeated viewings with the aim of understanding how different components of such scanpaths develop and influence search performance. Eye movements were recorded from 25 participants who had to find a hidden target in real-world scene images. Eight scenes were repeated throughout the task and randomly intermixed with eight novel scenes over six repetition blocks. The location of the target in each repeated scene was fixed. As expected, search efficiency systematically increased with repeated viewings and with a corresponding reduction in number of fixations. Critically, participants' eye-movement patterns were compared using the MultiMatch method (Dewhurst et al., 2012), which quantifies scanpath similarity over five different dimensions: Shape, Length, Direction, Position and Duration. Results revealed that similarity in shape, length and position systematically increased over repetitions, and scanpath similarity was, for all those dimensions, higher within-participants (i.e. comparing the same participant over repetitions of the same scene image) than between-participants (i.e. comparing different participants over repetitions of the same scene image). By relating those similarity measures with task performance, the present study demonstrates how different components of a scanpath adapt over repetitions in a memory-guided search task and specifies how those components contribute to efficient search strategies. Additionally, the findings suggest that individual top-down strategies are more important than bottom-up features provided by contextual features from the scene images. Taken together, these results shed new light on how different scanpath components unfold with experience and thereby contribute to developing a more optimal search strategy.

36.421 **Exploring the utility of incidental fixations in dynamic real-world visual search through mobile eye tracking** Grace L Nicora[1](grace.nicora@utah.edu), David Alonso[1], Kristina M Rand[1], Sarah Creem-Regehr[1], Trafton Drew[1]; [1]Department of Psychology, College of Social and Behavioral Science, University of Utah

Prior work investigating the role of fixation dwell time on incidental objects in visual search has primarily used static search arrays presented on computer screens. Previously, we found that time spent fixating an irrelevant item did not correlate with later recognition for having seen that item. However, in a search task where the target changed on every trial, dwell time on distractors correlated with later recognition (Hout et al., 2012). In the current study, we used mobile eye-tracking to investigate whether fixation behavior may act differently in a real-world dynamic search task involving navigation along novel paths. Participants were asked to memorize six target objects. We placed pictures of both the target and irrelevant distractor items in a series of hallways. We monitored eye-movements as they walked down the hallways looking for these items. Participants indicated when they recognized a target item, but they were not instructed to remember the locations of the items. At the end of the path, they were tested on their memory for the presence and location of all the items they encountered. Consistent with Hout et al.'s work, cumulative dwell time was lower for distractors that participants failed to recall seeing than those that were correctly recalled. Fixation dwell time appears to help encode the presence of the distractor items during navigation, but it did not have an effect on memory for where the items were located. While this suggests that location information is not incidentally encoded under these tasks constraints, in future work we hope to investigate the effects of fixation dwell time when the participants are explicitly asked to remember the location of the items. This work highlights differences observed when engaged in real-world search tasks as compared to the typical laboratory design.

36.422 **Don't Look Now: The influence of distractor features vs. spatial relevance on attentional deployment** Ellen O'Donoghue[1](0demo1@queensu.ca), Monica S Castelhano[1]; [1]Queen's University

Visual search performance is aided by knowledge of scene context and likely target positioning (Castelhano & Henderson, 2007; Neider & Zelinsky, 2006). In a recent study, Pereira and Castelhano (2017) demonstrated that attention is differentially deployed depending on the target-relevance of each scene region: in an abrupt-onset paradigm, target-relevant distractors were fixated upon and saccaded towards significantly more often than target-irrelevant distractors. In the present study, we examined whether the visual features of distractors influence attentional deployment over and above the spatial relevance of their positions. Distractors were placed in scene regions that were operationalized as either target-relevant or target-irrelevant, and were either visually similar or dissimilar to the target object. Participants saccaded towards and fixated upon target-relevant distractors significantly more often than target-irrelevant distractors. Interestingly, visual target-distractor similarity did not have an effect: only distractors appearing within target-relevant regions reliably attracted attention, regardless of their visual similarity to the target. These findings suggest that attention during search is distributed based on likely target positioning and, surprisingly, that attentional capture within scenes may be better predicted by spatial relevance than by visual feature similarity. However, previous research has also demonstrated that distractors are more likely to capture attention when they share categorical features with the target (Wyble, Folk, & Potter, 2013). We will further examine the potential interaction between the spatial relevance of distractor positioning and categorical target-distractor similarity, in order to assess the extent to which spatial relevance and distractor features differentially predict attentional deployment in search through real-world scenes.

36.423 **Visual Search for Medication Vials** Evan M Palmer[1](evan.palmer@sjsu.edu), Logan M Gisick[2]; [1]Department of Psychology, San Jose State University, [2]Department of Human Factors, Embry Riddle Aeronautical University

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When medical professionals administer an injectable drug, they must search for a medication vial that is typically small, visually indistinct, and stored near other similar looking medications. Every year, over 400,000 people die from medical errors and about one third of those deaths are medication-related. In a series of experiments, we investigated visual search for medication vials to determine which label properties lead to the quickest and most accurate search. In particular, we sought to determine whether features known to guide visual search in simple stimuli would also apply to these real-world stimuli. Using photo images of medication vials, we systematically varied the color density, text size, and text orientation of target vials. Participants were shown an image of the target medication vial for two seconds and then searched through a display of 12 vials, with six vials on the left and six on the right side of the screen. Participants reported which side of the screen contained the target vial, or if the target vial was absent from the display (10% of trials). In Experiment 1, participants were faster and more accurate to find target vials with high color density across all conditions. There was also an interaction such that when text orientation was vertical, small text was located faster, but when text orientation was horizontal, large text was located faster. In Experiment 2, we removed the glass bottles from the images and just displayed the labels alone to confirm that the results from Experiment 1 were due to label properties and not differences in the shapes of the bottles. We are currently investigating search efficiency for high color density vials with vertical vs. horizontal text orientation. These results indicate that visual attributes that efficiently guide search in basic science experiments also predict performance in search for medication vials.

36.424 **Sequence Learning in Hybrid Visual Search** Erica Westenberg[1](ewesten15@gmail.com), Jeremy Wolfe[2], Iris Wiegand[2,3]; [1]Department of Neuro-Cognitive Psychology, Ludwig-Maximilians-Universität München, [2]Brigham and Women's Hospital and Harvard Medical School, [3]Max Planck UCL Centre for Computational Psychiatry and Ageing Research

In "hybrid search", observers search through visual displays for any of several types of target items, which are held in memory. Studies have found that reaction times (RTs) grow with the log of the size of the memory set. Now suppose that targets appeared in a fixed sequence: for example, if the target was the cup on one trial, it would always be the fish on the next trial. In other paradigms, participants have faster reaction times when responding to stimuli that appear in a predictable sequence, even if they are not explicitly aware of that sequence. On the other hand, in hybrid search, observers seem to have trouble restricting memory search to a portion of a memory set. Can observers limit their memory search if they learn a target sequence? 24 participants aged 18-35 completed four blocks of a target localization task. First, they memorized 4 or 16 target items (varied over blocks). Observers performed a memory test to confirm that they knew these targets. Then, they searched for these targets among 3 or 15 distractors (varied over trials within a block). Targets appeared either in a fixed sequence over trials (20 repetitions per block) or in random order. Participants were unaware of the sequences before the experiment. After the experiment, we assessed participants' explicit knowledge of the sequence with a two-alternative forced-choice test and questionnaire, which we used to classify them as explicit "learners" (n=10) or non-learners (n=14). Learners had faster RTs and, importantly, shallower RT x memory set size slopes than non-learners. The shallower slopes suggest that learners could use knowledge of the next target to guide visual search and/or to restrict the effective memory set size. Further work will be required to determine if explicit knowledge of the sequence is required for this learning benefit.

36.425 **Detecting and localizing prostate lesions within half a second** Melissa Trevino[1](melissa.trevino@nih.gov), Todd S Horowitz[1], Ismail B Turkbey[2], Peter L Choyke[2], Marcin Czarniecki[2]; [1]Behavioral Research Program, National Cancer Institute, [2]Molecular Imaging Program, National Cancer Institute

Previous research has shown radiologists can discriminate "abnormal" from "normal" medical images at above-chance levels in a fraction of a second (Carmody, Nodine, & Kundel, 1981; Evans et al., 2013; Evans et al., 2016; Kundel & Nodine, 1975), without necessarily being able to localize the abnormality. This is referred to as gist perception. However, we do not know whether this phenomenon is a general property of expert medical perception or a specific feature of conventional chest radiographs and mammograms. Here we investigated whether radiologists can extract gist from multiparametric magnetic resonance imaging (mpMRI) of the prostate. Stimuli were 100 T2-weighted MRI images of the base, mid and apex regions of the prostate. Lesions (Gleason scores 6-9) were present in 50% of the images. Two groups of participants were tested, radiologists specializing in mpMRI (n = 11) and radiologists not trained in prostate imaging (n = 5). Images were presented for 500 ms, followed by a sector map of the prostate. Participants localized the lesion on the sector map, and then provided a confidence rating. While radiologists specializing in mpMRI performed well above chance at detecting the lesion ($d' = 1.1$, sd = 0.3), radiologists without prostate training performed at chance level ($d' = -0.1$, sd = 0.3). Curiously, both groups could localize the lesions above chance. These data extend the phenomenon of gist perception to the mp-MRI domain. Like mammographers, radiologists with prostate training can detect lesions in a glance. Unlike the mammography data, however, localization performance was well above chance, and predicted by detection performance (r = .80), suggesting that there may be enough information available in 500 ms to guide attention to the lesions.

36.426 **Examining the effects of task-irrelevant emotional scenes and individual differences in personality characteristics on performance in a visual search task** Monica L Rosen[1](rosen.monica@huskers.unl.edu), Lauren Bandel[1], Karl Kuntzelman[1], Michael D Dodd[1]; [1]Psychology, University of Nebraska-Lincoln

It is well established that emotional stimuli capture attention, but there are a variety of contexts in which ignoring emotional distractions and maintaining focus on the task at hand are critical (e.g. emergency responders). In the present study, we investigate a) whether task-irrelevant emotional stimuli would influence performance on a primary visual search task as a function of task difficulty and b) whether there are individual differences in personality characteristics which may provide insight into how irrelevant emotional stimuli influence attention. Participants performed a standard visual search task in which they discriminated the location of a rotated target letter among distractors, with the search display overlaid on a collage of four low-contrast, gray-scaled images (three neutral and one rated either highly negative or positive). The target letter was always present and responses were made by manually indicating the quadrant in which the target was located via a keypress. In experiment 1, only accuracy and RT measures were collected and performance was compared as a function of target location, image valence, and search set size. Experiment 2 served as a replication of Experiment 1 with the addition of eye movements being monitored to determine where individuals first fixate in the search display and how frequently they return to each search quadrant as a function of image valence. Participants from both experiments were also asked to complete a number of personality surveys. Our results showed that performance differed depending on the target location and image valence. Moreover, this effect was moderated by task difficulty such that larger search set sizes were less likely to be affected by image valence. These results provide insight into the interactive influence of emotional stimuli and task difficulty which provide further understanding into the relationship between emotion, attention, and performance.

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36.427 **Differences in Search Mechanics for Anxious Individuals and Individuals with an Autism Spectrum Disorder During Real-World Visual Search Tasks** Nicholas C.C. Russell[1](nicholas.russell@warwickgrad.net), David N. Top[1], Mikle South[1], Steven Luke[1]; [1]Department of Psychology, Brigham Young University

Introduction: Superiority in visual search tasks is often seen in individuals with autism spectrum disorders (ASD) and is frequently attributed to perceptual differences in visual processing (either a preference for local processing or a difficulty with global processing). Recent research, however, has suggested that these differences may instead be related to an atypical attentional system. In addition, research has also suggested that individuals with ASD may no longer demonstrate a visual search advantage when those searches involve real-world scenes. Similarly, differences in visual search have been seen in individuals with anxiety, compared to non-anxious typically developing (TD) individuals. Despite the high prevalence of anxiety symptoms in ASD, the extent to which these

Sunday PM

altered visual search profiles overlap had not been investigated. Method: Individuals with ASD (N = 30), anxiety (N = 27), and typically developing (TD) individuals (N = 49) completed two simple visual search tasks (41 trials of each) with real-world scenes (one to find a digit superimposed on the scene and the other to find an object placed in a contextually-relevant location). Eye movements were recorded to quantify three stages of the search process: initiation time (start of trial to first saccade), scan time (first saccade to first target fixation), and verification time (first target fixation to response). Results: Across conditions, the ASD group required longer initiation time than the anxiety and TD groups. Both the ASD and anxiety groups had a longer scan time and verification time than the TD group but were similar to each other. Conclusion: With real-world scenes, those with ASD and anxiety require more time for real-world visual search. The only aspect of search mechanics uniquely difficult for those with ASD is initiation time. This is consistent with theories proposing a difficulty disengaging attention as underlying real-world visual search difficulties in those with ASD.

36.428 **Using Virtual Reality [VR] to assess the effects of asymmetric vision loss on visual search performance** Hugo T Chow-Wing-Bom[1](hugo.chowwingbom@gmail.com), Tessa M Dekker[1,2], Pete R Jones[1,3,4]; [1]Institute of Ophthalmology, University College London, London, UK, [2]Experimental Psychology, University College London, London, UK, [3]NIHR Moorfields Biomedical Research Centre, London, UK, [4]Division of Optometry and Visual Science, School of Health Sciences, City University of London, London, UK

Many common blinding diseases, such as Glaucoma, begin in one eye. Being able to measure how asymmetric vision loss affects people's performance on everyday tasks may help to identify pathologies early, and could provide an important endpoint when evaluating new therapies. Here, we report a series of studies in which we used virtual reality to evaluate how simulated, asymmetric vision-loss affected response-speed on visual search tasks. In Experiment I, six healthy adults (25.8 ± 3.8 years old) performed a texture-in-texture visual search task, while whole-field blur of varying magnitude was applied independently to each eye. As expected, when the blur was bilaterally-symmetric across both eyes, increasing blur slowed response times ($P < 0.001$), and at very high levels the task became impossible. When blur was unilateral the 'better' eye was able to compensate to a degree, and the task was possible at all levels of blur. However, even in the unilateral condition, there was still a consistent effect of blur on response times ($P < 0.001$) – although the rate at which response times increased was less than in the bilateral-symmetric condition ($P < 0.001$). This means that asymmetric vision-loss continued to degrade search times, suggesting that this paradigm could be used as a potential biomarker for diseases such as Glaucoma. We will also present data from additional experiments (data collection ongoing), in which we assess the effects of Central vs. Peripheral blur, and of Artificial vs. Naturalistic search environments.

Acknowledgement: "The Biomedical Research Centre located at (both) UCL and Moorfields Eye Hospital" and "Moorfields Eye Charity"

Perception and Action: Decision making

Sunday, May 20, 2:45 - 6:45 pm

Poster Session, Pavilion

36.430 **Sequential Effects in Confidence** Shannon M Locke[1](sml726@nyu.edu), Pascal Mamassian[3], Michael S Landy[1,2]; [1]Department of Psychology, New York University, New York, New York 10003, [2]Center for Neural Science, New York University, New York, New York 10003, [3]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Dèpartement d'Ètudes Cognitives, Ècole Normale Supérieure, Paris, France

Confidence reports are characterised as subjective assessments of performance given the quality of the perceptual evidence in the current trial. However, sequential effects in confidence recently reported by Rahnev and colleagues (2015) show that confidence is modulated by trial history. Specifically, the level of confidence in one trial is predictive of that in the subsequent (confidence leak). The proposed explanation involves subjects updating their expectation of the next trial's difficulty according to the current confidence level. Unlike Rahnev et al., we examined sequential effects in confidence with fixed difficulty, but also variable prior and reward structure. On each trial, participants reported the orientation (left/right) of a tilted Gabor (fixed to $d'=1$), followed by a confidence report (high/low). Feedback was provided for the orientation response. Different reward-prior combinations were tested in 7 separate sessions. Confidence in the current trial was predominantly dependent on the correctness of the orientation judgment in the current trial (confidence reflects performance) and the confidence reported in the previous trial (confidence leak). The correctness of the orientation judgment in the previous trial and the reward gained in the previous trial had weak and inconsistent effects on confidence. Subjects with larger confidence leaks, as estimated by a 1-back regression, show strong and idiosyncratic structure in the autocorrelation of confidence reports over long time scales. Confidence leak has a substantial effect on confidence assessments. When confidence leak was large, confidence judgments correlated with trials much earlier in the session. Thus, one must proceed with caution when interpreting or modelling confidence ratings based on single-trial evidence. To attenuate these effects in data, it would be preferable to measure confidence using a relative judgment ("Are you more confident in the current decision than you were in the previous trial?").

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36.431 **Serial dependence for discriminating grating orientation at threshold contrast is driven by perceptual decisions** Huihui Zhang[1](zhanghuihui.cn@gmail.com), David Alais[1]; [1]School of Psychology, University of Sydney

Many studies have shown that recent history biases present perception, known as serial dependence, although it remains unclear whether it is driven by changes in perception or decision-making. Here we examined serial dependence for discriminating visual grating orientation (+45° or -45°) at threshold contrast. The grating was embedded in noise and its contrast was maintained at threshold level over trials (75% correct) by an Accelerated Stochastic Approximation procedure. Participants reported which orientation they perceived by clicking a mouse. To evaluate serial dependence, we conducted a linear regression of present orientation choice on present stimulus, previous stimulus, and previous choice. Unsurprisingly, the regression coefficient for present stimulus was significant. However, the regression coefficients for previous (i.e., 1-back) stimulus and previous choice were both not significant. Next, we repeated the same analysis for stimulus and choice but for larger n-back values. Positive regression coefficients for previous choices were found for trials that were 2-, 3-, 4- and 5-back from the present trial, while regression coefficients for previous stimulus were not significant over the same range. Next, we used lagged regression to evaluate the relative influence on present perceptual choice from previous series of choices. Similar to previous results, coefficients for previous choices from 2-, 3-, 4- and 5-back from the present trial were significant. Moreover, the value of coefficients decreased as the temporal distance from the present trial increased. In conclusion, our results suggest that (1) orientation discrimination at threshold contrast exhibits a positive serial dependence; (2) the serial dependence at threshold contrast originates from previous decisions rather than previous stimuli; (3) unlike traditional serial dependence which is strongest for the one back trial, serial dependence for orientation discrimination at threshold is not present at 1-back: it peaks at 2-back and declines gradually out to 5-back.

36.432 **Perceptual explaining away in depth judgements** Nils Neupärtl[1,2](neupaertl@psychologie.tu-darmstadt.de), Constantin A. Rothkopf[1,2,3]; [1]Cognitive Science Centre, Technical University Darmstadt, 64283 Darmstadt, Germany, [2]Institute of Psychology, Technical University Darmstadt, 64283 Darmstadt, Germany, [3]Frankfurt Institute for Advanced Studies, Goethe University, 60438 Frankfurt, Germany

Visual cues to depth are inherently ambiguous and uncertain. Classic research in vision science has demonstrated that human judgments of depth are closely predicted by Bayesian cue integration, which weights individual depth cues by their relative uncertainties to reach a more reliable estimate. While this weighting of cues is linear for the case of Gaussian variability, more complex interactions of cues will result in strongly non-linear cue weighting, therefore providing a stronger test of predictions of Bayesian computations. One such scenario is perceptual

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explaining-away, in which an auxiliary cue helps disambiguating the influence of two causes of a sensory measurement. Here we investigate whether human subjects utilize a known texture as auxiliary cue to infer size and depth of a ball when only a relative size cue is given in a 2d display and when a relative size cue is given together with stereo disparity in a VR display. In our experiment subjects decided in a 2AFC task which of two spherical objects, shown either on a computer screen or an HMD, was closer. The objects differed in their textures to appear as soccer, tennis or golf balls. Used size ratios were adjusted to match realistic size ratios. Further, we gathered eye tracking data in the 3d condition to investigate how decisions were related to looking times. Based on a probabilistic computational model in the Bayesian framework we inferred subjects' prior beliefs about size ratios. Our model takes uncertainty into account both for the perceived ratio and participants' prior belief and enables us to use the collected behavioral data to infer the shape of subjects' internal belief structure. The results show that human decisions in size judgments can be explained as perceptual explaining away, prior size ratios are quite accurate, and response probabilities scale linearly with looking times.

36.433 **The Neurodynamic Decision Variable in Human Multi-Alternative Perceptual Choice** Kielan Yarrow[1](kielan.yarrow.1@city.ac.uk), Carmen Kohl[1], Laure Spieser[2], Bettina Forster[1], Sven Bestmann[3]; [1]Dept. of Psychology, City, University of London, [2]Laboratoire Cognitive Neuroscience, Aix-Marseille Université, [3]Institute of Neurology, UCL

The human neural correlates of perceptual decision-making bear a remarkable correspondence to the predictions of sequential sampling models. However, to date, the research focus has been on binary choices, while real-world decisions typically offer more than two possible responses. Here, we describe a transcranial magnetic stimulation (TMS) paradigm capable of tracking decision-related evidence accumulation in four effectors while human participants perform two and four-choice perceptual decisions. Thirteen participants collectively contributed around 54,000 trials on a random-dot motion discrimination task. After pre-processing, around 30,000 non-TMS trials were used to estimate the best-fitting parameters of sequential sampling models, and around 14,000 TMS trials were used to estimate smoothed motor-evoked potential (MEP) signals associated with different possible responses. Direct comparison of these MEP-based signals, which appeared to provide a downstream readout of decision-making computations, to the accumulation profiles predicted by the leaky competing accumulator (LCA) model revealed marked qualitative similarities between model predictions and cortico-spinal signals. We thus demonstrate that TMS can be used to track the multi-alternative decision variable, and show that, in line with model predictions and findings from non-human primates, the number of choice alternatives affects the baseline level of neural accumulation in humans.

Acknowledgement: The Leverhulme Trust

36.434 **Understanding the accuracy-RT relationship: Model-free approaches and limitations of the drift diffusion model** Farshad Rafiei[1](farshad@gatech.edu), Dobromir Rahnev[1]; [1]School of Psychology, Georgia Institute of Technology

Understanding how long decisions take is of fundamental importance for uncovering the underlying mechanisms of perceptual decision making. Consequently, there has been an enormous interest in the subject and a long tradition of creating models to jointly predict choice and reaction time (RT) data. However, most previous studies only used two conditions to manipulate the speed-accuracy tradeoff (SAT): one with higher and one with lower speed pressure. Here we report on the results of a large study where we created five distinct SAT conditions and were thus able to describe with much higher precision the relationship between speed and accuracy. Subjects (N = 15) came for five separate sessions, completing a total of 5,000 trials each. The task was to indicate whether a Gabor patch presented for 33 ms was tilted clockwise or counterclockwise. We used such short stimulus presentation in order to precisely describe the speed of information propagation through the system. We found that the fastest median RTs were 230-250 ms with performance at chance level. Performance for higher median RTs increased steeply until reaching a plateau around 500-550 ms. Simulations from a drift diffusion model (DDM) instead suggested that performance should not saturate for at least another second. Further, we observed robust U-shaped curves for the RT difference between correct and incorrect trials as a function of accuracy. However, DDM could only generate increasing or decreasing curves. Finally, we showed that the curves of accuracy as a function of median RT had the same stereotyped shape across subjects. Based on our findings, we created a new measure of SAT that does not depend on DDM's parametric assumptions. Overall, our results demonstrate that DDM does not faithfully capture the dynamics of SAT and highlight the need for large, data-driven investigations of the true relationship between speed and accuracy.

36.435 **Decision-stage representation: Full distribution over possible choices or information about the most likely choice only?** Jiwon Yeon[1](j.yeon@gatech.edu), Dobromir Rahnev[1]; [1]School of Psychology, Georgia Institute of Technology

What is the nature of the internal representation at the decision stage? Most current theories assume that the decision-stage representation consists of a full probability distribution over possible choices (full probability model). Alternatively, it is possible that the decision-stage representation only includes information on the most likely choice (simple model). Here we report on the first attempt to empirically distinguish between these two possibilities. On each trial, we presented 49 circles displayed in four different colors. In the 4-choice condition, subjects (N = 32) indicated the dominant color (applied to 16 circles; non-dominant colors were applied to 11 circles each) among all possible colors. Critically, we also included a 2-choice condition, in which, after the offset of the stimulus, only two response options were presented – the dominant and a randomly selected non-dominant color. Based on the performance on the 4-choice condition (mean accuracy = 69.2%), the full probability model predicted significantly higher performance on the 2-choice task (predicted accuracy = 83.8%) compared to the simple model (predicted accuracy = 79.7%). The actual performance on the 2-choice condition (mean accuracy = 78%) was much closer to the prediction of the simple model. Formal model comparisons favored the simple model in 28 of the 32 subjects (total AIC difference between the two models = 260). Experiment 2 replicated these results with a different stimulus set (we used symbols, such as % and $, instead of colors) and a higher number of choices (6 vs. 4). Experiment 3 further replicated the main findings but with a different task, in which subjects always made two choices in a row. The results of the three experiments demonstrate that the internal decision-stage representation does not include a full probability distribution over possible choices; instead, it consists of information related exclusively to the most likely choice.

36.436 **HD-tDCS over right frontal eye field biases expectation in a free choice saccade task** Brandon J Caie[1,3](12bc10@queensu.ca), Jerrold Jeyachandra[1], Aarlenne Z Khan[2,3], Gunnar Blohm[1,3,4]; [1]Center for Neuroscience Studies, Queen's University, [2]École d'Optométrie, Université de Montréal, [3]Canadian Action and Perception Network (CAPnet), [4]Association for Canadian Neuroinformatics and Computational Neuroscience (CNCN)

Every choice is guided by the interaction between sensory information and internal goals. Choice behaviour however evolves with the course of actions and changing environments. To assess how sensory information and internal drives interact over time, we employed a free choice saccadic reaction time task. Participants responded to two choice targets that varied randomly in time of relative onset. Selection was faster and more probabilistic when the two options appeared close in time, while large temporal gaps led to slower, predictable selection of the early target. A competitive stochastic decision model investigated the relationship between reaction time distributions in terms of sensory evidence accumulation towards a decision and the prior probability of choice, and captured how target asynchrony influences choice and reaction time. Using a reinforcement learning component, we found that future choices are biased by the way we accumulate and expect sensory information relative to recent choice history; this manifested as competing alternation rate and repetition probability biases respectively. This tradeoff was mediated by the previous decision time and the growing urgency to act, providing reactive and proactive components of bias formation. Using fMRI-guided HD-tDCS, we probed choice history in human right frontal eye field, known to play a key role in the planning and execution of eye movements. While alternating choices were unaffected, repeated choices were more likely to be made to the visual hemifield contralateral to stimulation and under conditions of greater urgency. Thus, our results depict choice

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bias as an unfolding competition between sensorimotor processing and internal expectations involving the frontal eye field, and cast HD-tDCS as a novel method to target the mechanisms promoting expectation in choice behaviour.

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36.437 **Distinguishing the roles of dorsolateral and anterior PFC in visual metacognition** Medha Shekhar[1](bsmedha@gmail.com), Dobromir Rahnev[1]; [1]School of Psychology, Georgia Institute of Technology

Visual metacognition depends on regions within the prefrontal cortex. Two areas in particular have been repeatedly implicated: the dorsolateral prefrontal cortex (DLPFC) and the anterior prefrontal cortex (aPFC). However, it is still unclear what the function of each of these areas is and how they differ from each other. To establish the specific roles of DLPFC and aPFC in metacognition, we employed online transcranial magnetic stimulation (TMS) to causally interfere with their functioning during metacognitive computations. Subjects (N = 21) performed a visual discrimination task while providing confidence ratings. We delivered TMS on each trial to one of the following three sites: DLPFC, aPFC and the somatosensory cortex (S1; control site). We found a clear dissociation between the effects of TMS on the two prefrontal areas: DLPFC TMS lowered mean confidence ratings (mean difference with S1 TMS = -0.09, P = 0.006), whereas aPFC TMS increased metacognitive ability but only for the second half of the experimental blocks (mean difference with S1 = 0.22, P = 0.03). These results support a functional architecture where DLPFC extracts the strength of the sensory evidence and sends it to aPFC, which generates the actual confidence rating by potentially incorporating additional, non-perceptual information. Further, we simulated a hierarchical confidence generation model that incorporates these putative DLPFC and aPFC functions. Specifically, we modeled DLPFC TMS as a decrease in the sensory signal that is input to the metacognitive level and aPFC TMS as a decrease in the noise that corrupts the confidence signal. The simulations reproduced our behavioral results thus corroborating the proposed roles of DLPFC and aPFC in metacognitive computation. Our findings causally establish DLPFC and aPFC as distinct nodes in a metacognitive network and suggest specific contributions for each of these regions to confidence generation.

36.438 **Prospective decision making for dynamic visual stimuli** Ryuto Yashiro[1](doragon8328@gmail.com), Isamu Motoyoshi[2]; [1]Department of Integrated Sciences, The University of Tokyo, [2]Department of Life Sciences, The University of Tokyo

Predicting the future state of natural and social events is crucial for our adaptive behaviors. Whereas the sensory system predicts incoming inputs over a range of several hundred milliseconds, humans are governed by a variety of cognitive biases in predicting the future beyond a few seconds. To elucidate such biases, we investigated the characteristics of human prospective decision making upon the supra-second future of a random-walk stimulus. In our psychophysical procedure, a single Gabor patch (1.0 c/deg) changed horizontal position in accordance with a 1/f velocity noise (with cut-off below 4.7 Hz) over variable periods of time (T = 1, 2, or 4 sec). Average velocity over the presentation was set zero (i.e., no linear trend). After the stimulus disappeared, observers indicated within 0.5 sec whether the stimulus would move toward left or right over a particular period after stimulus offset (δT= 1, 2, 4 sec for each block). We applied logistic regression analysis to calculate the impact of velocity information at each temporal frame upon the observer's response. The analysis revealed that observer decisions tend to depend heavily on velocities at and soon before stimulus offset, especially after the last several reversals in motion direction. This tendency becomes less marked when the observers tried to predict events in the relatively far future (δT = 4 sec). These results support the notion that, when predicting the uncertain future, humans tend to focus heavily on the last few directional reversals just before they make a decision and to linearly extrapolate trajectory to estimate the future state.

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36.439 **Motion fluency and object preference: Robust perceptual but fragile memory effects.** Jonathan C Flavell[1](jonathan.flavell@york.ac.uk), Bryony McKean[1], Steven P Tipper[1], Alexander J Kirkham[1], Tim Vestner[1], Harriet Over[1]; [1]University of York, Department of Psychology

Perceptual processes quickly extract information from the environment to facilitate object identification and appropriate action (e.g. Tipper et al., 2006). Fluent stimulus processing can result in positive affect that is then attributed to the stimulus itself (e.g. in contrast, priming and presentation duration (Reber et al., 1998), symmetry, (e.g., Rhodes et al., 1999), and contour extraction (Erle et al., 2017, Flavell et al., 2017)). Fluent object motion can also lead to affect transfer, at least where the motion is directly assessed (e.g., Stevanov et al., 2012). However, there is little published research on the effects of motion fluency on object preference in situations where the motion judgement itself is not a task requirement. Our studies investigated four questions. 1) Does motion fluency (how smooth and predictable motion is) implicitly influence object preference? 2) Can object-fluency association be learnt from repeated exposure? 3) Do learnt associations generalise to situations where the object is rated following a static presentation (no motion cues). These questions around learning have real-world consequences. For example, a product advertised with high fluency might be preferred at the time but this preference might not transfer to seeing the object on a shelf. In seven experiments we examined motion fluency effects on object preference. We demonstrate that 1) fluent objects are preferred over disfluent objects, 2) object-motion associations can be learnt, and 3) learnt associations do not transfer easily to situations where the object is rated following static presentation. Episodic accounts of memory retrieval predict that emotional states experienced at encoding might be retrieved along with the stimulus properties. Though object-motion associations were learnt, there was little evidence for emotional reinstatement when the stimuli were stationary. This indicates that the retrieval processes is a critical limiting factor when considering visuomotor fluency effects on behaviour.

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36.440 **Feature-continuous motion judgements: Assessing different random dot motion displays** Riccardo Barbieri[1](rbrb914@gmail.com), Felix Töpfer[1], Joram Soch[1], Carsten Bogler[1], John-Dylan Haynes[1]; [1]Charité – Universitätsmedizin Berlin, corporate member of Freie Universität Berlin, Humboldt-Universität zu Berlin, and Berlin Institute of Health (BIH) Bernstein Center for Computational Neuroscience, Berlin Center for Advanced Neuroimaging, Departmen

In perceptual decision making experiments subjects are often asked to indicate a stimulus feature under different level of noise (Gold & Shadlen, 2007). In most cases the decisions require categorical judgements, for example binary choices between two different motion directions. Such categorical judgement tasks have important shortcomings: They do not reflect the inherently continuous nature of perception. And due to being binary they do not provide a graded trial-wise measure of precision. We developed a continuous version of the Random Dot Kinematogram (RDK – Newsome & Parè, 1988), in which the direction of motion varied from trial to trial, each time taken from the full range of directions. Each trial had a different level of motion coherence (Figure 1). We tested 12 subjects on three types of RDK (Transparent, Limited Lifetime White noise and Brownian) to observe which stimulus would lead to a better estimate of the motion direction (Pilly and Seitz, 2009). As expected, responses were less precise and slower with lower stimulus coherence (Figure 2). This is in line with predictions of a drift diffusion model extended to feature continuous tasks (Smith, 2016). Moreover we found that Brownian RDK is the most suited for the continuous report of motion direction. Both the Transparent and Limited Lifetime White-Noise stimuli induced a second component in the distribution of responses: the report of opposite direction (ROOD, Figure 3). Please note that in a standard RDK task with only two directions this would go unnoticed. The Brownian implementation yielded a single distribution of responses that spreads with decreasing coherence with no secondary peak. Therefore, Brownian RDK is most suited for studying continuous report of motion direction. We further conclude that feature-continuous decision making tasks capture perceptual performance, especially the accuracy, in more detail.

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36.441 **Cognitive models modulate action-perception coupling in perceptual multistability** Peter Veto[1], Marvin Uhlig[1], Nikolaus F. Troje[2], Wolfgang Einhäuser[1]; [1]Chemnitz University of Technology, Institute of Physics - Physics of Cognition Group, Chemnitz, Germany, [2]Department of Psychology, Queen's University, ON, Canada

Theories like "common coding" suggest joint representations of action and perception, which implies a bidirectional coupling between these domains. Effects of perception on action are self-evident. Evidence for direct effects of action on perception arises from perceptual bistability: congruent movements stabilize the interpretation of an ambiguous stimulus. Can cognitive processes affect such action-to-perception transfer? Observers viewed a structure-from-motion cylinder of ambiguous motion direction. Prior to the ambiguous stimulus, we presented unambiguous versions that suggest a mechanical model on how the cylinder connects to a rod; in the "belt-drive" condition the rod rotated in the same direction as the cylinder, in the "gear-drive" condition in the opposing direction. Observers rotated a manipulandum either the same way as the rod (congruent instruction) or in the opposing way (incongruent instruction). In the "belt-drive" condition, the congruent instruction translates to congruency between perception and manual rotation. In the "gear-drive" condition, the congruent instruction translates to *in*congruency between perception and action. If the action-to-perception transfer is not influenced by the internal model of the underlying mechanics, we would find that congruent movement stabilizes the percept in both conditions. If, however, the effect depends upon cognitive assumptions, we would find a more stable percept with incongruent movement in the "gear-drive" condition. Results showed a significant interaction between the trained mechanical model and the action-to-perception transfer. While the congruency-effect was present in the "belt-drive" condition, no difference in either direction was found following the "gear-drive" training. This suggests that perceptual and cognitive congruency effects nullify each other. Hence, the observers' internal model of a machine's operation influences action-to-perception transfer.

36.442 **That was awkward! How greetings go awry** Hongjing Lu[1,2](hongjing@psych.ucla.edu), Akila Kadambi[1], Nick Ichien[1], Shuwen Qiu[1]; [1]Department of Psychology, UCLA, Los Angeles, California, United States of America, [2]Department of Statistics, UCLA, Los Angeles, California, United States of America

Dyadic interactions can sometimes elicit a disconcerting response from viewers, generating a sense of "awkwardness". This phenomenon has not received systematic investigation, so it remains unknown whether general principles govern the subjective perceptions of awkwardness. Here, we focused on a range of greeting behaviors (handshake, fist bump, high-five) to examine the role of context and kinematic information in the social evaluation of awkwardness for greeting behaviors. We employed advanced computer vision techniques to present the same greeting actions in three different display types. All display types presented the same kinematic information but different contextual information: (1) Patch displays showed blurred scenes composed of patches ("superpixels"). (2) Body displays presented human body figures on a black background. (3) Skeleton displays presented skeletal figures of moving bodies. Participants viewed 34 activities (25 awkward and 9 natural greetings), all in one randomly-assigned display type, and rated the degree of awkwardness of each greeting behavior on a scale from 1 (surely natural) to 6 (surely awkward). Across all display types, participants were consistently able to discriminate between awkward and natural behaviors, suggesting that the kinematics of body movements primarily drives awkwardness judgments (although judgments were also affected by the amount of contextual information displayed). For example, the famous video of President Donald Trump shaking hands with his Supreme Court nominee was ranked highly awkward even for the body and skeleton displays, in which identity information was completely removed. Multidimensional Scaling (MDS) analysis revealed two underlying psychological dimensions: motor coordination (which accounted for most of the variability in awkwardness judgments) and touching duration. We conclude that the perception of awkwardness in greeting behaviors is based on general principles that rely primarily on kinematic cues. In particular, detection of failed motor coordination for body movements provides a key signal that a greeting has gone awry.

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Visual Memory: Working memory

Sunday, May 20, 2:45 - 6:45 pm

Poster Session, Pavilion

36.443 **We are not all the same: Different memory limits reveal different memory processes.** Young Seon Shin[1](yshin2016@fau.edu), Summer Sheremata[1, 2]; [1]Center for Complex Systems & Brain Sciences, Florida Atlantic University, [2]Department of Psychology, Florida Atlantic University

Visual working memory (VWM) maintains stable internal representations, however the amount of information that can be stored varies across individuals. To address the reasons for this variability, it is important to control for task difficulty between low- and high- memory individuals. We measured individuals' memory capacity and then made individualized memory tasks based on the capacity. We found that when set size increases, low memory performance individuals begin to make more errors. This leads to the hypothesis that when set size is high, low memory individuals remember more items at a cost for the precision of each representation. In contrast, high memory individuals selectively maintain items and therefore maintain a high degree of precision regardless of set size. In the present study, we demonstrated resolution in working memory also has different patterns between high and low memory capacity individuals using the continuous report task. We tested the precision of memory representations using individual set sizes defined as easy (K) and hard (K+2) condition. We found high memory capacity individuals have more precise memory representations when required to remember a number of items beyond their capacity. This distinct pattern of memory representation was preserved whether we used the standard mixture model or the swap model. The current study supports our hypothesis that VWM is processed differently based on individuals' memory limitations. Low memory individuals process more items relative to their memory limit resulting poorer resolution representations.

36.444 **No distinction between capacity and resolution in working memory: A single memory strength parameter explains the shape of visual working memory response distributions** Timothy F Brady[1](timbrady@ucsd.edu), Mark W Schurgin[1], John T Wixted[1]; [1]Psychology, University of California, San Diego

Over the past decade, many studies have used mixture models to interpret working memory data, drawing a distinction between capacity (number of items) and resolution (precision of representations) (Zhang & Luck, 2008), or proposing a mix of different precision memories (van den Berg et al. 2012). The results have led to numerous influential claims about the nature of working memory and long-term memory. Here we show that this entire class of models rely on erroneous assumptions about psychological similarity space and that once this is taken into account, no mixture model is required. Rather than 3 parameters (guess, precision, variability of precision), we equally accurately characterize the distribution of responses from continuous report using only a single free parameter (memory strength). The crucial insight is that while the color space used in these studies is perceptually uniform when comparing nearby colors, the distance between the target color and the foils range from small (1deg) to very large (180deg). This introduces well-known non-linearities in confusability for items with distances that vary considerably in physical space. In particular, we find an exponential-like fall-off in confusability with distance in 2D color space. After taking this non-linearity into account, a basic equal-variance signal detection model fits nearly all existing working memory studies. Our model also correctly makes novel predictions, including how the shape of the response distribution changes across different choices of color wheels and how the best fit parameters of mixture models differ when fitting orientation data rather than color data. This suggests a major revision of previous research, as it shows that the distinction between capacity and resolution is illusory. It also

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more directly relates previous models of long-term memory to the study of working memory; and offers a new theoretical framework for understanding the content and structure of working memory.

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36.445 **Sources of Error Underlying Visual Working Memory Manipulation** Hrag Pailian[1](hrag.pailian@gmail.com), George Alvarez[1]; [1]Psychology, Harvard University

To adapt to the dynamic world, visual working memory(VWM) allows us to store representations of objects and manipulate them in the face of new information. These processes, however, are not infallible. Computational models have revealed three main sources of storage errors: reduction in the precision of representations, forgetting, and object-location misbindings (Bays, Catalao, & Husain, 2009). Conversely, the source of manipulation failures remains unknown. Here, we address this issue by investigating the extent to which the aforementioned errors increase as a function of manipulation vs. storage (Exp1), manipulation load (Exp2), and interference from initial-stored representations (Exp3). Participants saw a display of empty placeholders that were briefly filled with colors (chosen from continuous color space) which then disappeared, requiring participants to store them in VWM. Placeholders either remained stationary or a varying number proceeded to swap positions, requiring the manipulation of color-location bindings. Participants reported the color of a cued item by clicking on a color-wheel. Response errors were separated into the aforementioned categories using the Swap Model. In Exp1, participants stored or manipulated 1 or 2 colors. No differences were observed in forgetting or misbinding rates, though precision decreased as a function of set size, but not manipulation. In Exp2, participants manipulated 2 items, such that two previously-color-occupied placeholders swapped positions (load=2) or one swapped with an empty placeholder (load=1). Precision and forgetting rates were constant across conditions, though misbinding increased as function of manipulation load. In Exp3, we confirmed that this increase in misbindings resulted from an item-limited manipulation resource (increased misbinding when manipulating 3 vs. 2 items) and not interference from a lingering representation (equal misbinding when placeholder moved to a previously-unoccupied-location vs. previously-color-occupied-location). These findings show that the source of errors in VWM manipulation reflect primarily an increased probability of misbinding as the number of manipulations increases.

36.446 **Distinct Attention and Working Memory Mechanisms Protect Internal Representations from Interruption** Nicole Hakim[1,2,3](nhakim@uchicago.edu), Tobias Feldmann-Wustefeld[1,2,3], Edward Awh[1,2,3], Edward K Vogel[1,2,3]; [1]Institute for Mind and Biology, University of Chicago, [2]Department of Psychology, University of Chicago, [3]Grossman Institute for Neuroscience, Quantitative Biology, and Human Behavior, University of Chicago

We use working memory (WM) to temporarily keep information in mind. When interrupted, decrements in WM performance are often observed. However, how task-irrelevant interruption affects WM and attention is not fully understood. Here, we use two different online measures of activity to more finely delineate how task-irrelevant interruption affects WM representations. We use lateralized alpha (8-12 Hz) power as an index of sustained spatial attention (Thut et al., 2006) and Contralateral Delay Activity (CDA) as an index of the number of items in WM (Vogel & Machizawa, 2004). In Experiment 1 (n=20), participants performed lateral change detection. We used four colored squares as interrupters, which appeared on the midline on 25% of trials. Following interruption, lateralized WM representations, as indexed by the CDA, sustained for several hundred milliseconds. On the other hand, attention, as indexed by lateralized alpha power, immediately became non-lateralized for several hundred milliseconds before re-lateralizing as participants began reorienting attention towards the attended hemi-field. In Experiment 2 (n=20), we were interested in whether top-down control modulates the impacts of interruption on performance by manipulating the probability (25% vs. 75%) of an interruption across blocks. Participants knew an interruption was more or less probable in each block. When there was a higher probability of interruption, participants reoriented their attention more quickly to the attended side and maintained lateralized WM representations for longer following interruption. The lateralized alpha suppression and CDA results from both experiments indicate that attention and WM are distinct mechanisms that work hand-in-hand to protect internally maintained representations. Additionally, top-down control is able to influence both of these mechanisms in an effort to revive and maintain internal representations following an interruption.

36.447 **The role of feature binding in the relationship between visual attention and visual short-term memory** Ivan D Annicchiarico[1](iannicchiari2016@fau.edu), Summer Sheremata[2]; [1]Florida Atlantic University, [2]Florida Atlantic University

Similar mechanisms underlie feature binding in visual perception and short-term memory. Feature binding is an essential process that allows us to perceive integrated objects. While feature integration in perception is well documented, it is debated whether it reflects the same cognitive and neural processes across different tasks. Importantly, feature-binding deficits have been found in Alzheimer's disease during visual short-term memory (VSTM). It is unclear whether these deficits reflect impairment in the binding of features independent of memory demands, or an impairment due to increased demands on the memory processes themselves. In order to understand these deficits, we need to know whether feature binding relies upon similar mechanisms across tasks in young, healthy adults. In a series of experiments, we therefore asked whether the performance cost for feature binding was similar across tasks in healthy young adults. Participants performed two tasks in which they had to identify a target based upon a single feature (shape or color) or binding of the same two features. In the attention task, participants were shown a target and then asked to report whether it appeared within a set of three colored shapes. In the VSTM task, participants performed a change detection in which they were asked to remember 3 colored shapes and then probed with a single colored shape at fixation. We then measured the correlation of feature binding cost (single feature performance – feature binding performance) across the two tasks. Across experiments, we found a moderately high correlation for the feature binding cost, suggesting similar mechanisms for feature binding in perception and memory. We therefore propose that feature binding relies upon the same cognitive mechanisms regardless of task demands.

36.448 **Both bottom-up and top-down control influence multiple working memory-driven attentional selection** Lingxia Fan[1](fanlingxia990@163.com), 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

Recent work shows that when two items are maintained in visual working memory (VWM), only the item on active state can guide attention, while the accessory item cannot. Thus, it raises significant questions that what factors determine which memory representation is currently active and can there exist two active templates in VWM at a time. With two experiments, we showed that bottom-up physical salience of item features and top-down retro-cue could jointly determine the status of VWM representations, making them active to guide attention in the search task simultaneously. In Experiment 1, participants were required to complete a visual search task while holding one color and one shape in VWM during the process. Color, shape or the conjunction of color and shape matched one of the search distractors or not. Slower RTs were found when color or conjunction of color and shape matched one of the search distractors but not for the shape match condition, indicating that color with higher salience in VWM can win the priority position to guide attention while the less salient shape cannot. In Experiment 2, we further investigated that whether two features with different salience in VWM could simultaneously guide attention when the less salient feature was prioritized through a retro-cue. The procedure was similar with Experiment 1 except that color or shape in VWM was cued to be more task-relevant after encoding. Results showed that both color and shape produced interference effects on search in shape-cue trials, demonstrating that feature with higher salience and the feature with less salience but prioritized by a retro-cue in VWM can concurrently be active templates to impact attentional selection. Therefore, both bottom-up and top-down control influence multiple VWM-driven attentional selection.

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36.449 **Contextual information of a memory episode influences serial dependence** Cora Fischer[1](cora.fischer@med.uni-frankfurt.de), Stefan Czoschke[1], Benjamin Peters[1], Benjamin Rahm[2], Jochen Kaiser[1], Christoph Bledowski[1]; [1]Institute of Medical Psychology, Goethe University Frankfurt, [2]Medical Psychology, Albert-Ludwigs University Freiburg

Serial dependence refers to a systematic bias that attracts present towards recent visual inputs. It has been assumed to increase the stability of perception, as most recent and attended input has the strongest bias. Recent studies have suggested that serial dependence is a mnemonic rather than a purely perceptual phenomenon, as it increases with longer memory periods. However, studies so far have required memorizing only a single item at a time. Hence, it remains unclear which factors besides temporal proximity influence serial dependence when multiple items are encoded into working memory. One possibility is that attraction could be tuned by factors that relate items to one another across trials. To examine this issue, we asked 49 young adults to encode and remember two sequentially presented stimuli (S1 and S2) per trial. They were random dot kinematograms (RDKs) with different directions, one of which was retrocued and had to be reported via continuous recall. In addition, RDKs were shown in either red or green, whereby color was task-irrelevant. Hence, across trials items could be related either by their corresponding serial position (e.g., previous with current S1) or by color similarity (e.g., previous and current green stimulus). Consistent with the literature we observed a clear attractive bias for the reported item toward the items presented in the previous trial. Importantly, serial dependence was enhanced for items with congruent serial position, i.e., the current S1 was attracted more strongly to the previous S1 than previous S2, and S2 was biased more strongly toward the previous S2 than previous S1. In contrast, color congruency did not modulate serial dependence. These findings indicate that task-relevant contextual information relates items across memory episodes and thus determines serial dependence in addition to temporal proximity.

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36.450 **Probabilistic retro-cues do not determine representational state in visual working memory** Blaire Dube[1](bdube@uoguelph.ca), Alanna Lumsden[1], Naseem Al-Aidroos[1]; [1]Department of Psychology, University of Guelph

To circumvent the capacity limitations of visual working memory (VWM), mechanisms exist that govern how information is represented in memory to ensure that the most relevant information guides behaviour. Retroactively cueing an item in VWM, for instance, affects both memory quality and representational state: A retro cue that indicates with 100% validity which item will later be probed enhances memory of that item, and 'activates' its representation such that it will bias selection towards perceptually similar inputs during visual search. However, when the retro-cue is less than 100% valid (i.e., probabilistic rather than deterministic) the effect of the cue on memory performance varies with manipulations to the proportion of valid trials. Here we investigated whether probabilistic and deterministic retro-cues also differ in their influence over representational state. Participants encoded two colored squares for a subsequent memory test. Following encoding, a spatial cue indicated to participants which item was most likely to be probed at the end of the trial. Cue validity was manipulated across blocks to be either deterministic (100% valid) or probabilistic (70% valid). On a subset of trials, no memory probe was presented and the trial instead ended with a visual search task in which a colored distractor—matching either the cued memory item, the non-cued item, or neither—was presented. As expected, in the deterministic retro-cue condition, the presence of a search distractor that matched the color of the cued item reliably slowed response times relative to trials with non-matching distractors. In the probabilistic retro-cue condition, however, search response times were comparable across all three distractor conditions, despite a reliable benefit to memory performance on valid relative to invalid trials. We suggest that, while probabilistic retro-cues improve memory of the cued item, they do not bias its representational state in VWM.

36.451 **Similar items repel each other in visual working memory** Chaipat Chunharas[1,3](cchunharas@gmail.com), Timothy F Brady[1], Rosanne L Rademaker[1], John T Serences[1,2]; [1]Psychology, University of California, San Diego, [2]Neuroscience graduate program, University of California, San Diego, [3]Medicine, KCMH, Chulalongkorn University

Previous studies show systematic biases when visual features are remembered over short delays. However, some studies find biases toward ensemble statistics such as the mean of all presented features (attraction bias), while others find the opposite (repulsion bias). Here we investigated the factors that determine the direction of bias and whether biases have a functional benefit. When individual item representations are less reliable, ensemble-level representations may be more useful. However, when individual items are more reliable, repulsion biases could help reduce confusion between similar representations. To evaluate repulsion or attraction biases, we used a continuous color report task with two memory items. We independently manipulated the fidelity of the color targets (encoding times of 50/150/500ms) and the distance between the targets in feature space (differences of 20º/45º/90º/135º). Bias direction was quantified as the proportion of reports away from the un-probed item. When encoding time was relatively long (500ms), repulsion became monotonically stronger as color distance decreased. This suggests that subjects exaggerated the distance between increasingly similar items when they were higher fidelity. At a shorter encoding time (150ms), the repulsion biases instead peaked when the targets were 45º apart. This suggests that the fidelity of two very similar colors (i.e. 20º apart) became too low to register as distinct representations. Lastly, when encoding time was short (50ms), repulsion biases deceased overall – with representations attracted toward the average hue. This indicates that when fidelity is low, people relied on group-level representations. We provide evidence that the degree of repulsion vs. attraction depends on the strength and the similarity of the individual representations. This is consistent with the idea that such biases are adaptive ways for the visual system to overcome its biological limitations, allowing systematic errors to occur to maximize the usefulness of concurrent representations.

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36.452 **Reduced oculomotor capture by working memory contents under two- vs. one-item memory load suggests one item at a time is held in an active state** Valerie M Beck[1](vbeck@psych.udel.edu), Timothy J Vickery[1]; [1]Department of Psychological and Brain Sciences, University of Delaware

Representations maintained in visual working memory (VWM) can exist in either an "active" or "accessory" state such that an item in an active state can interact with attentional guidance, but an item in an accessory state cannot. Frequent attentional capture by VWM-matching items under one-item memory load suggests that item is in an active state, but it is unclear whether the states of multiple items in VWM will be active, accessory, or a mixture of the two. Extant studies have relied on continuous variables like manual response times (RTs), and the subsequent results might obscure capture – especially if VWM representations cycle through active and accessory states. Unlike RTs, oculomotor capture provides a discrete measure – did the first eye movement go toward the target or the distractor? Therefore, we examined oculomotor capture by VWM-matching distractors under both high and low VWM load. Participants were presented with one or two colored squares to remember, then asked to saccade to a left/right target disk while eye movements were recorded. Once the target disk was fixated, participants completed a forced-choice memory test. On some trials, a distractor disk appeared above/below central fixation simultaneous with the target. Either the target or distractor could appear in a VWM-matching color. Eye movements were more frequently directed to a VWM-matching distractor compared to a non-matching distractor both with a one-item (28% vs. 7%; $t(18)=5.60, p< .001$) and two-item (13% vs. 8%; $t(18)=3.97, p< .001$) memory load. Critically, when multiple items were maintained in VWM, oculomotor capture by a VWM-matching distractor occurred, though at a reduced rate compared to a one-item memory load (13% vs. 28%;

t(18)=5.67,p< .001). The current results suggest that, in absence of task demands to maintain both VWM items in an active state, only one item at a time was held in an active state.

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36.453 **Independent stores for relative and absolute spatial location in visuospatial working memory** David Aagten-Murphy[1](david.aagtenmurphy@gmail.com), Paul M Bays[1]; [1]Department of Psychology, Cambridge University

Visuospatial working memory enables us to maintain access to visual information for processing even when a stimulus is no longer present, due to occlusion, our own movements, or transience of the stimulus. In the real world, the visual stimuli we need to remember are rarely seen in isolation. Instead, at any given moment, there are usually innumerable other objects visible in a scene that can act as reference points ("visual landmarks") for improving spatial localization (Byrne and Crawford, 2010; Deubel, 2004; Obhi and Goodale, 2005). However, given the limited resources of visuospatial working memory (Bays & Husain, 2008; Zhang & Luck, 2008), what are the consequences of remembering additional object-relative information? To investigate this question, we had participants reproduce the spatial location of a stimulus from a memory array after a short delay. Persistent landmark stimuli were presented on some trials, potentially enabling participants to encode additional relative spatial information. We observed that, when landmarks were present, there was a substantial decrease in localisation variability for stimuli in their vicinity, with the effects decreasing as distance from the landmark increased. Critically, this improvement was not associated with any cost to the precision of egocentric estimates, suggesting that relative spatial information represents an additional, independent spatial cue for memory recall. An optimal integration model, in which relative (allocentric) spatial information was combined with absolute (egocentric) spatial information, accurately captured human performance. In the presence of two landmarks, enhanced localisation precision was evident near both, but the magnitude was reduced compared to the single landmark case. This suggests that spatial information encoded relative to each landmark competed for the same limited resource. In complex scenes, with many potential landmarks present, this highlights the importance of landmark selection for the dynamic allocation of memory resources.

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36.454 **Multiple visual working memory items can guide attention and facilitate perceptual processing** Jamal R Williams[1,2](jrw002@ucsd.edu), Timothy F Brady[1], Viola S Störmer[1]; [1]Psychology, University of California, San Diego, [2]Cognitive Science, University of California, San Diego

Previous research has shown that contents of visual working memory (VWM) can guide attention to features that match those actively held in mind. This memory-based attentional guidance has been shown for a single item, but whether similar guidance occurs for multiple items in VWM is under debate. Furthermore, it is unclear whether VWM contents can facilitate perceptual processing in tasks that do not require a narrow focusing of attention. Here we demonstrate that VWM can guide attention and facilitate visual processing of features that match the memory content, even for two items. Participants were instructed to remember one or two colors while performing another task. In Experiment 1, on 80% of the trials, instead of reporting the memory color, participants performed an unrelated visual search task in which the target either appeared in a circle that matched the color held in VWM or not (as in Soto, 2005). Participants were faster in finding the target when it matched the memory color relative to when it did not for both set sizes even though the memory color was uninformative in the search task (SS2; t(19)=-2.5,p< 0.05), consistent with automatic memory-based guidance. In Experiment 2, instead of a visual search task, we used a perceptual dot estimation task in which participants had to determine which one of two briefly presented dot arrays showed an overrepresentation of one color (as in Fang, Becker, & Liu, 2017 VSS). We found that the number of dots required to accurately identify the target array was significantly lower when the target color matched a memory color, suggesting that VWM contents facilitate visual processing. Importantly, this pattern was present for single and multiple memory items (SS2; t(28)=-2.6,p< 0.01). Overall, this suggests that two items held in VWM can affect perceptual tasks and attentional guidance in a relatively automatic fashion.

36.455 **The Effects of Structural Regularity on Working Memory Representations** Lilian Azer[1](lazer001@ucr.edu), Weiwei Zhang[2]; [1]Cognitive Psychology, University of California, Riverside , [2]Cognitive Psychology, University of California, Riverside

Previous experience and long-term memory can influence various aspects of working memory representation and processing. The present study has assessed how structural regularity of to-be-remembered information affects item and configural encoding in visual working memory (VWM) using Xie and Zhang's (2017) dual-trace Signal Detection Theory model. With this model, item and configural information in VWM can be characterized as discrete and continuous components, respectively. Two types of structural regularity, face versus non-face and goodness-of pattern, were tested in two experiments. Experiment 1 tested VWM for a set of stimuli that had matched low-level physical attributes but differed continuously on faceness rating in a modified change detection task. In this task, observers were required to retain four face or non-face stimuli over a 1-s retention interval and then reported whether a cued item in the test display was an old or new stimulus on a 6-point confidence scale. The resulting Receiver Operating Characteristics (ROC) curves were fit with the dual-trace Signal Detection Theory model, producing estimates of item and configural encoding. No significant difference was found in either measure for face and non-face stimuli. Nonetheless, there was a more liberal bias for face than non-face stimuli, leading to more false positives for faces. Experiment 2 replaced face versus non-face stimuli with dot-array patterns that differed in pattern goodness. Good patterns were remembered better than poor patterns, largely due to increased configural encoding for good patterns. Together these findings suggest that structural regularity of memory stimulus at different levels (category versus exemplar) have dissociable effects on VWM storage.

36.456 **Is source information automatically available in working memory?** Hui Chen[1](psychenhui@gmail.com), Richard Carlson[2], Brad Wyble[2]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, China, [2]Department of Psychology, The Pennsylvania State University, United States

In everyday life it is commonplace to remember a fact without its source. For instance, we all have some experience of recognizing a person but being unable to recollect where or when we met that person. This phenomenon was termed source memory failure/source amnesia, which has been studied extensively in long-term memory (Mitchell & Johnson, 2009). Most people, though, share the intuition that they will be able to remember the source of information that they have just recently encountered. Recent experiments, however, have challenged this intuition by demonstrating frequent source errors for information that had just been attended, encoded, or/and held in working memory (WM) momently before (Chen, Carlson, & Wyble, in press at Psychological Science ; Chen, Swan, & Wyble, 2016). In our experiments, participants were asked to judge the congruency between two color representations from one single object (i.e., ink color and identity of a color word) or two distinct objects (i.e., color of a square and identity of a color word) for several repetitions, and were then unexpectedly asked to report the source of one color representation. The results consistently showed participants' inability to report the source of a color representation, even though the color had just been attended and/or encoded into WM. This counterintuitive effect has been replicated and extended in a variety of contexts. In an extension, observers were even unable to report whether a perfectly recognized animal word was presented in English or Mandarin in an immediate incidental memory test. This is the first study showing source amnesia in the context of WM with young healthy participants. These novel findings suggest a cognitive-economy view of memory function, in which source information of an attended/encoded item is only stored in WM when it is in accordance with the goals of the observer.

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36.457 **Strategic working memory performance may confound the interpretation of cumulative task statistics** Benjamin E Cuthbert[1](0bec@queensu.ca), Dominic Standage[1], Martin Paré[1], Gunnar Blohm[1]; [1]Centre for Neuroscience Studies, Queen's University

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The mechanisms underlying the storage limitations of visual working memory are controversial. Some models assume that a discrete number of items can be stored (Zhang and Luck, 2008), while others posit that many representations with variable mnemonic precision can be retained (van den Berg et al, 2012). Typically, these models are fit to performance data from tasks that rely on summary statistics, such as the estimation of capacity on change-detection tasks or the estimation of precision from continuous report task error distributions. This approach ignores the influence of context-dependent strategies for task performance. Here, we investigate whether such strategies can improve task performance and confound the interpretation of performance statistics. On a whole report task, participants were presented with stimulus arrays containing up to 8 stimuli and reported the colour of all test items from a discrete array of equidistant colours. This approach allowed us to determine the accuracy of each selection on a trial-by-trial basis and to retain a measure of precision in colour space. Early results are mostly consistent with a recent continuous-response, whole-report study (Adam, Vogel, and Awh, 2017). We observed that response error distributions become increasingly diffuse with increased memory load, and found a downward trend in precision throughout successive responses. When a task manipulation was introduced at response onset to investigate output interference, some participants were unaffected, while others showed significant performance deficits. The possibility that different cognitive strategies were responsible for these differences prompted the use of generative modeling techniques to capture this behaviour. For example, late-trial responses (e.g. responses 5-8) were made with accuracy exceeding chance, and a model including strategic guessing produces very similar error distributions. This approach has the potential to reveal cognitive strategies employed during visual working memory tasks and to provide a novel description of high-load storage limitations.

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36.458 **The role of task-irrelevant space in non-spatial working memory** Masih Rahmati[1](masih.rahmati@nyu.edu), Thomas C Sprague[1], Clayton E Curtis[1,2], Kartik K Sreenivasan[3]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University, [3]Department of Psychology, New York University Abu Dhabi

Previous studies have demonstrated that the contents of visual working memory (WM) can be decoded from the spatial patterns of brain activity in visual cortex (e.g., Serences et al., 2009; Harrison & Tong, 2009; Rahmati et al., 2017). Results such as these support the sensory-recruitment model of WM, which posits that the neural populations in visual cortex involved in stimulus perception are also involved in the maintenance of WM representations. Feedback signals from frontal and parietal cortex, accordingly, are thought to help keep these sensory representations in a state that can be easily used to guide behavior contingent on WM (Curtis & D'Esposito, 2003; Postle, 2006). Here, we test the hypothesis that the maintenance of a non-spatial feature (i.e., orientation) is supported by retinotopic codes. We used fMRI and population receptive field mapping to identify retinotopic visual maps in occipital cortex and along the dorsal parietal cortex (Mackey, Winawer, & Curtis, 2017). We then examined WM-related activity in these visual maps as participants performed a delayed orientation discrimination task. On each trial, participants maintained the orientation of a single sample Gabor over a 10.5 second delay period. After the delay, they compared the memorized orientation to that of a probe Gabor presented in the quadrant diagonal to the sample. We used two inverted encoding models (IEM), one to reconstruct the orientation of the sample (Ester et al, 2013) and one to reconstruct the spatial locus of WM from the population activity in each visual map (Sprague et al, 2014). Although location information was irrelevant to task performance, occipital and parietal areas tracked the sample and upcoming probe locations. Importantly, orientation could be decoded best from the original sample location, suggesting that spatial signals may help keep non-spatial sensory representations in a state that can be accessed for memory-guided decisions.

36.459 **Using affective ratings to test competing hypotheses about differences in active and accessory states in visual working memory.** David De Vito[1](ddevito@uoguelph.ca), Mark J. Fenske[1]; [1]Department of Psychology, University of Guelph

The multiple state theory of working memory suggests that representations held in working memory are separated into two states: a currently-relevant active representation and accessory memory items held for future use. While the characteristics and consequences of active versus accessory states have been the subject of several investigations, the exact neurocognitive mechanisms that move representations between the two states remain unclear. Of the two competing hypotheses, one suggests that inhibition is applied to keep a representation in an accessory state, while the other suggests that accessory representations simply receive less top-down cortical amplification than active representations, but are not subjected to inhibition. Here we capitalize on the different affective consequences for stimuli whose memory representations are subjected to inhibition (negative ratings) or active enhancement (positive ratings) to test these competing hypotheses. On each trial participants memorized four items and then were cued to focus on a single item within memory. They then completed either a visual search or an affective evaluation task. Search times were slower when a search distractor matched the colour of the active item but not when it matched the colour of the accessory item, replicating findings of a division in working memory whereby only active items guide attention. Also, accessory items were affectively devalued compared to baseline and active memory items. This finding of devaluation supports the hypothesis that inhibition is used to keep representations in an accessory state, and adds to past findings that similar mechanisms of attention and emotion govern prioritization in working memory and the prioritization of external stimuli.

36.460 **Cerebellum added to Working Memory Networks revealed by Meta-analysis of Activation Likelihood Estimation of fMRI sites in n-back tasks** Sheila Crewther[1](s.crewther@latrobe.edu.au), Gemma Lamp[1], Peter Goodin[2,4], Robin Laycock[1,3], David Crewther[1,4]; [1]School of Psychology and Public Health, La Trobe University, Melbourne, Victoria, Australia., [2]Florey Institute of Neuroscience and Mental Health, Heidelberg, Victoria, Australia, [3]School of Health and Biomedical Sciences, RMIT University, Melbourne, Victoria, Australia, [4]Centre for Human Psychopharmacology, Swinburne University, Melbourne, Victoria, Australia.

Understanding of the underlying neural correlates of working memory (WM) have undergone consistent evolutions with increasing sophistication of imaging and analysis tools. Hence we aimed to re-examine the normative functional neuroanatomy of a common WM measure, the n-back task, using meta-analysis of voxel-based activation likelihood estimation (ALE) software, with stricter inclusion criteria and incorporating many more studies. A decade ago an influential meta-analysis revealed five fronto-parietal regions, allocating each region a role based on existing literature. Today 95 of a possible 999 papers reviewed fit the inclusion criteria. While the original study compared only stimuli type across studies, the current meta-analysis also compared WM load. Results revealed the fronto-parietal regions previously established, but also demonstrated significant and consistent activation of a number of other sites including the bilateral cerebellum, bilateral insula and anterior cingulate. Importantly, meta-analysis revealed that regardless of n-back stimulus type or WM load, common areas are consistently activated across studies. This updated meta-analysis should help to shift the focus of research away from traditional functional segregation of cognitive tasks, towards a core network view of WM including cerebellum. .

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36.461 **Atomoxetine has no effects on visual working memory but benefits motivation** Mavis Kusi[1](9mk11@queensu.ca), Lindsey T. Thurston[1], Catherine Crandell[1], Martin Paré [1]; [1]Centre for Neuroscience Studies, Queen's University

Atomoxetine (ATX) is a selective catecholamine reuptake inhibitor and is increasingly prescribed to individuals with attention deficit hyperactivity disorder (ADHD). To date, there is equivocal evidence that ATX improves cognitive abilities in nonhuman primates and humans, including people with ADHD. We examined the effects of ATX on visual working memory in three adult female rhesus macaques. The animals were tested with a range of ATX doses (0.03-3 mg/kg) that span beyond the therapeutic range (0.5-1.4 mg/kg); they were orally administered the drug. A visual sequential comparison (VSC) task was used to assess visual working memory. Each trial of the VSC task begins with the presentation of a

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memory array of 2 to 5 coloured stimuli. Following a one second retention interval, a test array is presented and the animals are required to make a saccade to the item that has changed colour to receive a liquid reward. We found that ATX did not significantly enhance the monkeys' response accuracy and response latency in the VSC task. However, ATX had significant effects on improving the animals' motivation (task engagement) in the VSC task. To more directly assess motivation following the administration of ATX, we developed a task with a progressive ratio (PR) schedule of reinforcement. In this PR task, the animal must fixate a gradually increasing number of visual stimuli to obtain the reinforcer (liquid) and the number of fixations made to obtain the last reinforcer (the breakpoint) estimates motivation. We found that the animals' breakpoint in the PR task varied as a function of ATX dose, with an optimal dose falling within 0.3 and 3 mg/kg. Overall, our results suggest that ATX does not directly enhance visual working memory and may be best described as boosting motivation.

36.462 **The impact of topological change on visual working memory updating** Ning Wei[1] (nwei@bcslab.ibp.ac.cn), Tiangang Zhou[1], Yan Zhuo[1], Lin Chen[1,2]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, [2]The Innovation Center of Excellence on Brain Science, Chinese Academy of Sciences

The question what is the fundamental unit of visual working memory (VWM) is one of the most important and controversial issues. Based on the "early topological perception" theory, a unique perspective to describe the representation of VWM was proposed. To investigate this question, we used an updating version of a color change detection paradigm (Kessler, 2015). Participants were presented with a memory array or two successive memory arrays. They were asked to store the items' colors of the most recently appeared memory array and to report whether the color of test item changed. The colors of the second array were either consistent with the first array (repetition) or totally different (updating). There were two experimental conditions beyond the baseline in our studies. In shape-change condition, the items' shapes (task irrelevant) in second array were different from the first memory array (e.g. a solid square to a solid disk). In topology-change condition, the item changed its topological properties (e.g. a solid square to a hollow square). In four experiments, we consistently found that there was significant repetition benefit effect on color memory in the baseline (when there is no shape-change), and shape-change condition. However, the repetition benefit effect diminished in the topology-change condition, since the item was perceived as a new object with the topological change which impaired the original memory. Therefore, the different repetition benefit effects in shape-change and topology-change conditions supported that the topological change triggers updating of information in VWM. Meanwhile, it suggested that the fundamental representation in VWM may be topological defined perceptual object.

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36.463 **Visual interference does not contaminate working memory: Testing the "perceptual reuse" theory** Qian Yu[1](qianyu@jhu.edu), Chaz Firestone[1], Jonathan I. Flombaum[1], Marina Bedny[1], Justin Halberda[1]; [1]Department of Psychological & Brain Sciences, Johns Hopkins University

Is working memory simply the reactivation of perceptual representations? Decoding experiments with fMRI suggest that perceptual areas maintain information about what we have seen in working memory. But is this activity the basis of visual working memory itself? If it is, then perceptual interference during maintenance should impair our ability to remember. We tested this prediction by measuring visual working memory performance with and without interfering mask gratings, presented during the memory delay at the same location as the to-be-remembered stimulus. Participants memorized the orientations of 1-4 sample gratings, which appeared for 800ms. After a 5-second pause, the participants were exposed to a target grating in the same location as one of the sample gratings, and the target grating was rotated either clockwise or counterclockwise relative to the original. The task was to identify the direction of change. The key manipulation was that during the 5-second maintenance period, participants were exposed either to a blank screen, or to a rapidly changing stream of mask gratings in each of the previously occupied positions. We reasoned that if visual working memory relies on early perceptual substrates then exposure to conflicting masks that putatively activate the same substrates should impair performance (relative to no-mask trials). In other words, there should be interference, between the rapidly changing perceptual inputs and the perceptually maintained memory representations at the same retinal location. Contrary to this prediction, there was no difference in performance between the masked and unmasked conditions. We did, however, observe significantly reduced accuracy as a function of set size (the number of sample gratings in a trial). This evidence suggests that representations in early perceptual brain regions may not play a functional role in maintaining visual features.

36.464 **Efficient coding in visual working memory accounts for stimulus-specific variations in orientation recall** Robert Taylor[1](rtt23@cam.ac.uk), Paul M Bays[1]; [1]Department of Psychology, University of Cambridge

Recall of visual features from working memory shows stimulus-specific variation in both bias and precision (Bae & Flombaum, 2014; Pratte et al., 2017). While a number of existing models can approximate the average distribution of recall error across target stimuli, attempts to capture the way in which error varies with the choice of target have been ad hoc. Here we extend Bays' (2014) neural resource model – whereby stimuli are encoded in the normalised spiking activity of a population of tuned neurons – to provide a principled account of these stimulus-specific effects. Following previous work (Ganguli & Simoncelli, 2014; Wei & Stocker, 2015), we allow each neuron's tuning function to vary according to the principle of efficient coding. This principle states that neural responses should be optimised with respect to the natural frequency of stimuli in the environment. For orientation stimuli this means incorporating a prior that favours cardinal over oblique orientations. While continuing to capture changes to the mean distribution of errors with set size, the resulting model accurately described stimulus-specific variations in recall error. Additionally, the efficient coding model predicts a repulsive bias away from cardinal orientations – a prediction that ought to be sensitive to changes in the environmental statistics. We subsequently tested whether shifts in the stimulus distribution influenced response bias to uniformly sampled target orientations. Across adaptation blocks we manipulated the cardinality of non-target array items by sampling from one of two bimodal distributions: a congruent distribution with peaks centred on cardinal orientations and an incongruent distribution with peaks centred on oblique orientations. Prior to adaptation observers were repulsed away from the cardinal axes. However, exposure to the incongruent distribution produced systematically increasing biases away from oblique orientations that persisted post-adaptation. This result confirms the role of prior expectation in generating stimulus-specific effects and validates our neural framework.

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36.465 **From location to configuration: Does the Structure of a Display stick in memory as strongly as target location?** Ryan E O'Donnell[1](ryanodonnell7@gmail.com), Hui Chen[2], Baruch Eitam[3], Brad Wyble[1]; [1]Department of Psychology, College of the Liberal Arts, Pennsylvania State University, [2]Department of Psychology, Zhejiang University, [3]Department of Psychology, University of Haifa

A recently discovered phenomenon, termed Attribute Amnesia (AA), demonstrates an inability to report an attribute of an attended item, even when that attribute was used to successfully perform a task in the immediately preceding trial. For example, when asked to locate a letter among digits, participants could not remember the specific letter they were locating when asked to identify it in a surprise question. However, Chen & Wyble (2015b) demonstrated that location is strongly spared from this effect and may be automatically consolidated into memory regardless of its relevance. Yet, it is unknown whether the automatic encoding of location information extends to other aspects of the display, such as the spatial structure of a display itself or the items surrounding a target. In this study, participants underwent a standard AA paradigm, in which they located a letter among number distractors followed by a surprise question that asked for the letter's identity. Importantly, participants were

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also asked in the surprise trial to identify the structure of the target-distractor display itself, which randomly varied between two configurations: top-left/bottom-right or top-right/bottom-left in a notional rectangle. The structure of this display should not be task relevant, as the location of the distractor would not help participants find the target. Memory performance on the structure (73.33%) of the display was statistically higher than chance of 50% (30 participants, $p < .01$), indicating that participants remember not just the location of the target but also the configuration of the display. This work provides insight into the nature of representations that are constructed automatically as we perform a task.

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36.466 **The minimal proactive interference observed with real-world objects in a visual working memory task is not location-specific** Robert Walter[1,2](r1walter@ucsd.edu), Timothy F Brady[2]; [1]Cognitive Science, University of California, San Diego, [2]Psychology, University of California, San Diego

Proactive interference (PI) is when an item previously held in memory interferes with a new memory item. Previous studies investigating PI in WM with real-world objects have shown it to be critically dependent on the method of presentation. When items are presented sequentially, there is a large PI effect (Endress & Potter, 2014). When objects are presented simultaneously at different spatial locations, there is little effect of repeating items trial to trial (Makovski, 2016), suggesting little role for LTM in the standard change detection task, even with real-world objects. We asked whether the distinction between simultaneous and sequential was because location representations were critical to PI. On each trial, participants were shown a 4-object array for 1s. Objects didn't repeat across the experiment. After a brief delay, one of the object's location was cued, followed by a 7AFC task. The choices included the object from the cued location and other two locations of the current trial, objects from the same locations on the previous trial, and an object that didn't appear in the current or previous display. Selection of objects shown in the previous trial is evidence of PI, and selection of the location-matched objects is evidence that location is an important part of this PI. Overall, we found only a small PI effect, consistent with previous literature on simultaneous displays. However, this small PI effect was not dependent on spatial location: participants were as likely to select a foil from the previous trial that did not match the current target location as one that did. The lack of location specificity may indicate that the main distinction between simultaneous and sequential presentation is not location per se. Instead, participants may rely on different strategies when encoding simultaneous displays and sequential displays, relying more on LTM representations in sequential presentation.

36.467 **Comparing the capacity limitations of working memory for locations and features** Cody W McCants[1](cmccan03@mail.bbk.ac.uk), Tobias Katus[1], Martin Eimer[1]; [1]Birkbeck, University of London

The capacity of working memory (WM) is limited, both in terms of the number of items that can be simultaneously stored and the precision of stimulus representations in WM. Previous studies using electrophysiological recordings have found that the amplitude of event-related contralateral delay activity (CDA) during the retention of visual information in WM reflects the number of items being memorized, up to an asymptote at around 3 items. This is usually interpreted as evidence for a discrete capacity limitation of WM. However, because these CDA results were obtained in tasks requiring memory for features or objects, it is unknown whether the same discrete capacity limits also apply to WM for spatial locations. To answer this question, we compared memory performance and CDA amplitudes in two tasks where participants either had to memorize the colours or the spatial locations of items. WM load was manipulated for both tasks (1, 2, 3 or 4 items). CDA amplitudes increased with the number of memorized items, up to an asymptote of 3 items. Importantly, identical load-dependent CDA enhancements were observed in the colour and location tasks (i.e., no task type x load interaction), as confirmed by Bayesian analysis. This was mirrored in task performance, where K-estimates of memory capacity were similar in both tasks. These results suggest that the same discrete capacity limits that apply to WM for non-spatial features also constrain the number of locations that can be held in WM. This raises important questions about the role of spatial location for representations of objects and features in WM.

Acknowledgement: ESRC

36.468 **Working memory for sequentially presented objects does not rely on location to bind features** Sebastian Schneegans[1](ss2361@cam.ac.uk), William J Harrison[1], Paul M Bays[1]; [1]Department of Psycholgy, University of Cambridge

Spatial location is believed to have a special role in binding other visual features both in perception and working memory. Consistent with this view, a recent study found specific deficits in feature binding in working memory when memoranda were presented sequentially at the same location, compared to a control condition in which items were presented sequentially at different locations (Pertzov & Husain 2014). In the present study, we investigated whether these apparent working memory deficits may in fact be due to perceptual interference at the stage of encoding, as suggested by findings of temporal crowding (Yeshurun, Rashal & Tkacz-Domb, 2015). Subjects viewed four oriented bars in discriminable colors, and, following a brief delay, were cued with a color to reproduce the orientation of one bar from memory. Bars were presented sequentially either at the same or different display locations. Importantly, we varied the inter-stimulus interval (ISI) either to match the duration from the previous study (300 ms), or to be twice as long so as to remove any possible perceptual interference between stimuli. In the conditions with a short ISI, we reproduced the findings of the original study: there was a higher proportion of swap errors (i.e. incorrectly reporting the orientation of a non-cued stimulus) when memoranda were presented at the same location than when memoranda were presented at different locations. However, this effect of stimulus location disappeared in the long ISI conditions, without any decrease in overall performance. Our results suggest that the increase in swap errors is due to interference at the level of perception rather than due to a binding deficit specific to working memory. We argue that temporal order can replace the special role of location in feature binding when items are presented sequentially.

Acknowledgement: Wellcome Trust 106926

36.469 **How does aging affect the human visual short-term memory task for object-location and name-location binding?** Raju P Sapkota[1](Raju.Sapkota@anglia.ac.uk), Ian van der Linde[1,2], Shahina Pardhan[1]; [1]Vision and Eye Research Unit, School of Medicine, Anglia Ruskin University, Cambridge, UK, CB1 1PT, [2]Department of Computing and Technology, Anglia Ruskin University, Cambridge, UK, CB1 1PT

It is believed that age-related differences in human visual short-term memory (VSTM) performance reflect an impaired ability to retain bound object representations (viz., form, name, spatial, and temporal location). This study examined how healthy aging affects memory retrieval using a set of sequential form and/or location/name memory recognition tasks in which one component (form, location) was cued.Thirty-six young healthy adults (mean age 22.1 years, SD 2.6) and thirty-six normally aging older adults (mean age 69.2 years, SD 6.0), all with normal vision and hearing (self-reported), completed five tasks: 1. Object recognition for two or four sequentially displayed objects; 2. Spatial location recognition for two or four sequentially displayed objects; 3. Combined object-location recognition for two or four sequentially displayed objects; 4. Object recognition with location priming for two or four sequentially displayed objects; 5. Combined name-location recognition for four sequentially displayed objects. Significantly lower performance for older adults in location recognition [task 2, $F(1,35) = 5.17$, $p = 0.03$, 2 (Sequence lengths) × 2(Age groups) ANOVA], object-location binding [task 3, $F(1,35) = 13.45$, $p = 0.001$, 2 (Sequence lengths) × 2(Age groups) ANOVA], object recognition with location priming [task 4, $F(1,35) = 5.53$, $p = 0.02$, 2 (Sequence lengths) × 2(Age groups) ANOVA], and name-location binding [task 5, $t(70) = 3.35$, $p = 0.001$, Independent Samples t-Test] were found. The performance of normally aging adults was selectively and significantly lower than young adults in VSTM tasks that required object-location or name-location binding. Older adults exhibited greater impairment when object location (rather than form) was used as a cue during memory retrieval. The

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findings add to the 'memory source' model by suggesting that age-related decline in VSTM binding performance are driven by impairments in spatial location recognition and priming.

36.470 **Using performance discontinuities to estimate individual Working-Memory Capacities in serial recall tasks** Jonas K Lindeløv[1](jonas@id.aau.dk); [1]Department of Communication and Psychology, Aalborg University

Although formal models are frequently used to infer working-memory capacity (C) from visual array tasks (Cowan, 2001, Table 2; Luck & Vogel, 2013), Complex Span tasks, on the other hand, are typically scored using variants of the mean number- or the mean proportion of correctly recalled items (e.g. Redick et al, 2012; Conway, 2005). Though useful as indices, they are not interpretable as C, partially because they are confounded by the range of spans presented to the subjects. I propose the "rate change" score of working-memory capacity which has just three parameters: (1) C, the subject's capacity which marks a shift from (2) PC , a high Bernoulli-proportion of correctly recalled items, to (3) Pother, a lower Bernoulli-proportion of recall for further presented items. A Bayesian rate-change model was implemented in JAGS (Plummer, 2003) and applied to data from 46 subjects (25 males) aged 22.4 years (SD = 2.0) who completed a computer-based operation span tasks with four repetitions of spans one through seven, i.e., 28 trials. The population C is 3.7 chunks (95 % CI = 3.2 to 4.2) in line with previous estimates (Cowan, 2001). C constitutes a sharp performance discontinuity between a high rate of recall in working memory (PC = 94.5 %, 95 % credible interval = 93.2 to 96.1 %) and a low rate of recall for items exceeding C (Pother = 9.1 %, CI = 3.9 to 15.0 %). Individual Cs are strongly linearly related to ability as derived from a three-parameter logistic model (r = .987). Classical complex span scores, on the other hand, are non-linearly related to ability. In summary, C is an accurate measure of working-memory ability. Furthermore, the parameters of the rate-change model are theoretically meaningful and robust to the choice of presented spans (e.g., 2-5 vs. 2-7).

36.471 **Does visual working memory adapt to the nature of anticipated interference?** Benchi Wang[1](wangbenchi.swift@gmail.com), Jan Theeuwes[1], Christian N.L. Olivers[1]; [1]Vrije Universiteit Amsterdam

Visual working memory (VWM) is an important memory buffer to briefly store visual information for ongoing tasks. Evidence shows that VWM representations can be protected against interfering input during the maintenance period. In this study, we investigated whether the protection of VWM representations is selective with regards to the anticipated nature of the interference, or whether VWM automatically protects all information in the wake of interference. In two experiments, participants were required to memorize both the color and the orientation of grating pattern for a memory test at the end of a delay period. During the delay period, either an additional color or an additional orientation memory task was presented. Which type of interfering task (color or orientation) would be presented was predictable with 80% likelihood. The results showed that memory for orientation survived orientation interference better when orientation interference was expected than when color interference was expected. Likewise, memory for color survived color interference better when color interference was expected than when orientation interference was expected. We conclude that visual working memory protection is adaptive in that it selectively shields the feature for which it expects the strongest interference.

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36.472 **Real-world objects are not stored in bound representations in visual working memory** Yuri A. Markov[1](yuamarkov@gmail.com), Igor S. Utochkin[1], Timothy F Brady[2]; [1]National Research University Higher School of Economics, Russia, [2]Psychology, University of California, San Diego

When storing multiple objects in visual working memory, observers sometimes misattribute perceived features to incorrect locations or objects. These "swaps" are usually explained by a failure to store object representations in a bound form. Swap errors have been demonstrated mostly in simple objects whose features (color, orientation, shape) are easy to encode independently. Here, we tested whether similar swaps can occur with real-world objects where the connections between features are meaningful. In Experiment 1, observers were simultaneously shown four items from two object categories (two exemplars per category). Within a category, the exemplars could be presented in either the same (two open boxes) or different states (one open, one closed box). After a delay, two exemplars drawn from one category were shown in both possible states. Participants had to recognize which exemplar went with which state. In a control task, they had to recognize two old vs. two new exemplars. Participants showed good memory for exemplars when no binding was required. However, when the tested objects were shown in the different states, participants were less accurate. Good memory for state information and for exemplar information on their own, with a significant memory decrement for exemplar-state combinations suggest that binding was difficult for observers and "swap" errors occurred even for real-world objects. In Experiment 2 we used the same tasks, but on half of trials the locations of the exemplars were swapped at test. We found that participants ascribed incorrect states to exemplars more frequently when the locations were swapped. We conclude that the internal features of real-world objects are not perfectly bound in VWM and can be attached to locations independently. Overall, we provide evidence that even real-world objects are not stored in an entirely bound representation in working memory.

Acknowledgement: Program for basic Research at HSE

36.473 **The Capacity for Depth: Working Memory in Multiple Depth Planes** Dawn M Sarno[1](dawn.sarno@Knights.ucf.edu), Mark B Neider[1]; [1]Department of Psychology, College of Sciences, University of Central Florida

The extent to which depth information engenders benefits to attentional processing is inconsistent across a variety of tasks (e.g., visual search, multiple-object tracking, working memory). One factor that may underlie disparate findings regarding depth is working memory load. In the present studies, we systematically manipulated working memory load to determine how distributing visual information across multiple depth planes affects overall memory capacity. In two experiments, participants performed a change detection task where they determined whether a change occurred in an array of colored cubes. In Experiment 1 items appeared in one or two depth planes. Targets either appeared in their own depth plane, or in the same depth plane as distractors across seven set sizes (2-8). The results indicated a 9% decrement in accuracy for multiple depth planes at set size 3, but a 6% benefit for multiple depth planes at set size 5. In Experiment 2, we examined how the distribution of items in multiple depth planes affects performance. Targets either appeared in their own depth plane or items were evenly distributed between two depth planes. In order to evenly distribute items only set sizes 4, 6, and 8 were used. Improved accuracy (7%) was found for displays with items evenly distributed compared to arrays where the target was in its own depth at set size 8. Interestingly, in both experiments participants exhibited working memory benefits associated with depth when the number of items in the display exceeded average maximum capacity (~4 items in both experiments as measured by Cohen's K). Overall, these results suggest that when working memory load is below max capacity depth information is not useful. However, when memory load exceeds max capacity participants can utilize depth information to bolster memory processes, and effectively increase capacity.

36.474 **Working memory for depth indicates a serial-position effect** Ke Zhang[1](1060180725@qq.com), Jiehui Qian[1]; [1]Department of Psychology, Sun Yat-Sen University

One of the subsystems of Baddeley's model on working memory is visuo-spatial sketchpad. It involves temporarily holding and processing visual information and spatial information. Although research on visual working memory is extensive, most studies employed visual stimuli presented at the fronto-parallel plane and few involve depth perception. To our knowledge, working memory for depth has not been investigated yet. Here, we explored depth working memory (DWM) by using a change detection task and an estimation task. The memory items were presented at various depth planes perpendicular to the line of sight, with one item per depth plane. The depth planes were separated by relative disparities ranging from -0.51◦ to 0.51◦ with a step of 0.17◦ using a Wheatstone stereoscope. Participants were required to make judgment on depth where the target (one of the memory items) located. We found that: 1) the change detection accuracy was much lower than that reported for visual working memory; 2) the memory performance (accuracy and estimation error) degraded with the number of memory items presented (set size); 3) the

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accuracy was higher for items presented at the nearest and farthest depth planes in relation to participants; 4) the performance was better when the probe was presented along with the other items originally in the memory array. These findings suggest that storage for depth information is more limited and imprecise than that for visual information, and the memory performance improves if references are provided. In addition, the advantage for memorizing the nearest and farthest depth suggests a serial-position effect, and indicates that DWM depends on the egocentric distance between an observer and the to-be-remembered object.

Acknowledgement: National Natural Science Foundation of China (31500919)

36.475 **Agent Identity Drives Adaptive Encoding of Biological Motion into Working Memory** Quan Gu[1](guquanpsy@zju.edu.cn), Zaifeng Gao[2], Xiaochi Ma[3], Xiqian Lu[4], Hui Chen[5], Mowei Shen[6]; [1]Department of Psychology and Behavioral Sciences, Zhejiang University, [2]Department of Psychology and Behavioral Sciences, Zhejiang University, [3]Department of Psychology and Behavioral Sciences, Zhejiang University, [4]Department of Psychology and Behavioral Sciences, Zhejiang University, [5]Department of Psychology and Behavioral Sciences, Zhejiang University, [6]Department of Psychology and Behavioral Sciences, Zhejiang University

To engage in normal social interactions, we have to encode human biological motion (BM, e.g., walking and jumping), the most salient and biologically significant kinetic information encountered in everyday life, into working memory (WM). Critically, each BM in real life is produced by a distinct person, carrying a dynamic motion signature (i.e., identity). Whether this motion-driven identity influences WM processing of BM remains unknown. Here we addressed this question by examining whether the clothing colors of people are extracted into WM when memorizing their actions. Two opposing hypotheses were tested: (a) WM only stores the target action (element-based hypothesis), and (b) WM stores both action and irrelevant clothing color (event-based hypothesis) interpreting each BM as an event. We required the participants to memorize actions while ignoring clothing colors, and examined the fate of irrelevant color by probing an irrelevant-change distracting effect. If the color was extracted into WM, the change of color in the probe would lead to a significant distracting effect on the action performance. We found that WM encoding of BM was adaptive: Once the memorized-actions had distinct identities, WM adopted an event-based encoding mode regardless of memory load, probe type, and the color setting of the memory array (Experiments 1, 2b, 3, and 4). However, it switched to an element-based encoding mode when the memorized-actions shared the same identity (Experiment 2a) or were inverted (Experiment 5). Overall, these findings suggest that motion-driven identity information has a significant effect on WM processing of BM.

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36.476 **The effects of aroma on capacity and precision of working memory** Motohiro Ito[1,2](moto.1100525@gmail.com), Jun I Kawahara[1]; [1]Hokkaido University, Department of Psychology, [2]Japan Society for the Promotion of Science

Recent studies have suggested mixed effects of aroma on allocation of attention (e.g., Colzato, Sellaro, Paccani, & Hommel, 2014). Ito and Kawahara (2017) reported reduced attentional blink effects under aroma exposure conditions (e.g., rosemary, lavender, and peppermint). However, their study found no correlation between changes in mood states induced by odors and the degree of reduction in the attentional blink effect, thus suggesting that exposure to these aromas directly affected the allocation of attention. Given that working memory plays a critical role in the allocation of attention, the present study focused on working memory capacity and the precision of memory representation, and examined whether exposure to aromas directly improved working memory components without changing internal states. Specifically, participants in Experiment 1 were administered the operation span task (Turner & Engle, 1989) to measure working memory capacity regarding executive and phonological functions, while wearing a rosemary-scented sanitary mask (or an odorless mask as a control condition). The results indicated that working memory capacity significantly increased under the rosemary aroma condition relative to that under the control condition. Experiment 2 measured the precision of the memory representation regarding executive and visuospatial functions. A new group of participants performed a visual working memory recall task in which they stored a set of color stimuli in memory and reported the color of an item by clicking on a color wheel. The results revealed that precision did not vary across odor conditions. Importantly, both experiments indicated that the mood states (e.g., pleasantness and arousal) did not change before or after exposure to either aroma. These results suggest that exposure to rosemary aroma directly improved the phonological function specific to the capacity but not the precision of the memory representation, without a change in mood state.

36.477 **The Mental Muscle: Effects of Concurrent Effortful Physical Action on Visual Working Memory** Marcus J Cappiello[1](mcapp001@ucr.edu), Weizhen Xie[1], Weiwei Zhang[1]; [1]University of California, Riverside

Action and cognition are closely intertwined in everyday life. For example, human observers frequently incorporate eye movements in mental representations and processes. However, how concurrent physical activity influences cognition beyond the oculomotor system remains unclear. Here, we ask how exerting an effortful physical action, such as hand gripping, impacts visual working memory (VWM), a core cognitive process. Using a novel choice paradigm (Experiment 1), we first evaluated how holding a handgrip to different levels (20%, 30%, 45%, 65%, and 90%) of the maximal voluntary isometric contraction (MVC) equated in perceived effortfulness to holding different number of items (1, 2, 3, 4, and 6) in VWM. This iso-effort pattern (i.e., working memory load equivalent in effort to a given physical load) can be captured by a logarithmic function, suggesting a systematic tradeoff between these two types of effort, potentially due to some shared mechanisms for physical and cognitive efforts. Experiment 2 replicated these findings from Experiment 1 and further examined how exerting different levels of handgrip force (20% vs. 45% MVC) directly affected performance in a change detection task performed concurrently. We found that the physical load of 45% MVC (vs. 20% MVC) reduced the number of items retained in VWM at a memory set size of 6, but not at smaller memory set sizes. Critically, across participants this reduction significantly correlated with the decrease in the iso-effort working memory load from 45% to 20% MVC estimated from the choice paradigm, ruling out an alternative account based on general dual-task cost. Together, these findings provide preliminary support for the direct competition between physical and cognitive efforts. Given the ubiquitous involvement of effortful physical activities in everyday life, the current study sheds light on the extent to which some core cognitive processes may be affected by physical strain.

36.478 **Attentional responses while looking for changes: effect of pathological ageing.** Moreno I Coco[1](moreno.cocoi@gmail.com), Carolina Maruta[2], Mário Carvalho[4], Catarina Campos[2], José Santos Victor[5], Isabel Pavâo Martins[2,3], Sergio Della Sala[1]; [1]Human Cognitive Neuroscience, Psychology, University of Edinburgh, UK, [2]Department of Clinical Neurosciences and Institute of Molecular Medicine, University of Lisbon, [3]Department of Neurology at Hospital Santa Maria, Lisbon, Portugal, [4]Centre of Linguistics, University of Lisbon, Portugal, [5]Institute for Systems and Robotics, Instituto Superior Técnico, Lisbon, Portugal

Mild Cognitive Impairment (MCI) refers to a progressive cognitive decline that can lead to Alzheimer Disease. Recent literature on MCI stressed the importance of looking at eye-movement responses as a key marker for cognitive decline. In the present study, we investigated the role that attentional responses play on the maintenance and access of visual information held in working memory.14 participants with MCI and 16 age-matched controls performed a change detection task on 120 photographs of naturalistic scenes (60 experimental/change trials, 60 fillers/no change trials), while being eye-tracked. We manipulated high-level semantic changes on a critical object in each scene under three experimental conditions: Congruency (it became another object), Location (it moved to another location) or Both (it changed and moved). We analyzed the detection accuracy and the distance of the closest fixation from the center of the critical object. MCI participants performed significantly worse than the control group. Both groups were better at remembering the change when the critical object changed Location, or when Both features changed, than when the change involved Congruency, a condition which proved particularly challenging for the people with MCI. Considering eye-movements, we found that the closer the participant's eye fixation was to the critical object, the more likely the change would be detected. Crucially, healthy controls were able to foveate closer to the center of the object in correct trials compared to people with MCI, particularly in the Congruency condition. This indicates that MCI patients had more difficulties attending at purely semantic changes, and consequently, failed to recognize them more often than healthy controls. These preliminary results suggest that attentional responses and high-level processing of semantic information are good proxies to the formation of and access to visual memories, and can be revealing about healthy and pathological ageing.

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Monday Morning Talks

Faces: Development and disorders

Monday, May 21, 8:15 - 9:45 am, Talk Room 1

Moderator: Sheng He

41.11, 8:15 am **Infants preferentially attend to faces when viewing them with the left eye but not the right eye** Kirsten A Dalrymple[1,2](kad@umn.edu), Brad Duchaine[3], Jed T Elison[1]; [1]Institute of Child Development, University of Minnesota, [2]Australian Research Council Centre of Excellence in Cognition and its Disorders, [3]Department of Psychological and Brain Sciences, Dartmouth College

Infants show an interest in faces from birth (Johnson & Morton, 1991). In both children and adults, face recognition is more dependent on the right hemisphere (RH) than the left hemisphere (LH) of the brain. Does the RH also drive infants' early interest in faces? To answer this question, 3-month-old infants (n=53) were recruited to view moving schematic faces paired with scrambled faces on a screen. Infants were randomly assigned to a viewing condition: binocular (BIN), left eye open (LEO), or right eye open (REO). Research suggests that the nasal retina develops before the temporal retina (Lewis & Maurer, 1990). Thus, early in infancy (i.e. prior to 6-months) visual information should travel predominantly from one eye to the contralateral hemisphere (LeGrand et al., 2003). Other work suggests little-to-no visual information transfer between hemispheres prior to 2-years-of-age (Liegeois et al., 1997, 2000). Following this logic, the BIN infants in our study would be expected to process the stimuli with both hemispheres, while LEO infants should process the stimuli primarily with the RH, and REO infants with the LH. We recorded the infants' eye movements using a screen-mounted camera and coded looking behavior. Overall, BIN infants spent more time looking at faces than scrambled faces ($p=0.03$). There was no difference in looking behavior for LEO or REO groups ($ps>0.10$). However, in the second block of trials, BIN infants and LEO infants spent more time looking at faces than scrambled faces ($ps< 0.009$), but REO infants had no preference ($p=0.939$). Thus, in later trials, infants processing the stimuli with the RH demonstrated a preference for looking at faces, while infants using the LH only did not. This effect did not extend to non-face objects (flowers). These findings suggest that infants' early interest in faces is mediated by the right hemisphere of the brain.

Acknowledgement: NIMH R01MH104324 to J. Elison

41.12, 8:30 am **Early visual exposure to faces is sufficient and necessary for prepping the FFA for future specialization in tactile face processing in the blind** Rui Dai[1](dairui18@foxmail.com), Zirui Huang[2], Xuchu Weng[3], Sheng He[1,4]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, Beijing, China, [2]Department of Anesthesiology, University of Michigan Medical School, Ann Arbor, Michigan, United States of America , [3]Center for Cognition and Brain Disorders, Hangzhou Normal University, Hangzhou, China, [4]Department of Psychology, University of Minnesota, Minneapolis, Minnesota, United States of America

The fusiform face area (FFA) is a core cortical region of face processing. Its sensitivity to faces is largely innate and tuned by visual experience. However, the nature of interaction between genetic specification and experience shaping for FFA remains unclear. In this study, we investigated the role of visual experience at different time points of an individual's early development in the cross-modal face specialization of the FFA. Subjects (n=38) consist of four groups: congenital blind, early blind, late blind and low vision. All subjects were trained for about 3 hours on tactile recognition of man-made embossed faces and other complex object categories. Functional magnetic resonance imaging (fMRI) data were acquired while subjects performed the tactile task both before and after training. While no face selective activation was detected before training in any group, results show a robust face-selective activation in the presumed FFA region in the early blind subjects after training. However, face-selective activation was not seen in FFA or other brain regions in the congenital blind or late blind subjects. Our results support a very strong genetic determination of FFA's specialization in face processing, that even after no visual experience for more than 14 years in early blind subjects, their FFA could quickly become engaged in cross-modal processing face information. Notably, the fact that no consistent face-selective activation was found in congenital blind subjects suggests that the specialization of FFA for face processing requires an initial kick-start of visual exposure to faces.

41.13, 8:45 am **The Perceptual Deficit in Congenital Prosopagnosia** Irving Biederman[1,2](bieder@usc.edu), Emily X Meschke[3], Rafael S Maarek[4], Eshed Margalit[4,5], Sarah B Herald[4,6]; [1]Psychology, University of Southern California, [2]Neuroscience, University of Southern California, [3]Computational Neuroscience, University of Southern California, [4]Biomedical Engineering, University of Southern California, [5]Neuroscience, Stanford University, [6]Neuroscience, Dartmouth College

Despite decades of investigation of prosopagnosia, the nature of the perceptual deficit underlying this condition has never been rigorously assessed. Nor even has it been established if there is a perceptual deficit, as opposed to a deficit in memory or a failure of view invariance. Individuals classified as prosopagnosic do have difficulty in discriminating some non-face visual entities. Performance on a minimal simultaneous match-to-sample test (Fig. 1) in which the participant must select the face that is an exact match to the sample from a foil: a) firmly establishes that there is a perceptual component to prosopagnosia, b) correlates with the magnitude of face configural effects, and c) accounts for much of the predictable variance of other validated measures of face recognition abilities, such as the CFMT, Faceblind.org, or the PI20. These findings suggest that the scores yielded by the various measures, although not ostensibly measuring perceptual processing, are largely—if not solely—reflecting perceptual effects. Individuals who show poor performance on the match-to-sample test also show deficits in their discrimination of fine metric differences between non-face stimuli, but only when these stimuli are complex, such as teeth, where the location of the differences are uncertain. The underlying deficit in prosopagnosia can arise from a dearth of large, overlapping receptive fields in posterior face-selective areas, e.g., FFA. In typical subjects, the overlap leads to activation of r.f.s with centers far removed from the features, thus serving to magnify the perceptual impact of small metric differences. With small r.f.s, the lack of overlap in the r.f.s in face-selective areas may explain why prosopagnosics do not show configural effects (Fig. 2) and why their deficit in distinguishing fine metric differences among non-face objects is apparent only when the objects are complex (Fig. 1) but not when discriminating simple geons (Fig. 3).

Acknowledgement: Dornsife Research Fund, NSF

41.14, 9:00 am **Deficient learning from unfamiliar face repetitions in developmental prosopagnosia: evidence from diminished fMRI repetition suppression of the FFA and decreased multi-voxel pattern similarity of the MTL** Yuan-Fang Zhao[1](distancejay@gmail.com), Yiying Song[1], Jia Liu[1]; [1]State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University

Humans gradually learn from unfamiliar face repetitions to achieve expert face recognition. However, for individuals suffering developmental prosopagnosia (DP), a neurodevelopmental disorder specifically impairing face recognition, it is unknown how they are impaired in facial experience accumulation. Here we used repetition suppression (RS) and multi-voxel pattern analysis to comprehensively investigate the neural deficits of DP during unfamiliar face repetitions. We found that both RS of bilateral fusiform face area (FFA) and pattern similarity of bilateral medial temporal lobe (MTL) approximating the perirhinal cortex (PrC)/hippocampus were abnormal in DP, indicating deficits in both perceptual processing in the FFA and memory maintenance in the MTL. Moreover, resting-state functional connectivity (RSFC) between the right FFA and left PrC/hippocampus was also disrupted. Further exploratory factor

analysis indicated that the multi-stage deficits in DP were not only caused by propagation from upstream perceptual disruptions, but also contributed by independent disruption in downstream memory stage. In addition, pattern similarity of the left hippocampus/PrC was related to DP's severity in long-term face memory deficit. In short, our study provided the first systematical neural evidence that DPs were deficient in learning from unfamiliar face repetitions and cast new light on the way in which unfamiliar faces may become familiar in normal population.

41.15, 9:15 am **Mismatch of face fixation preference and retinotopic tuning of face perception in autism spectrum condition** Matthew F Peterson[1](mfpeters@mit.edu), Amanda J Haskins[1], Ian Zaun[1], Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology

Why is face recognition impaired in autism spectrum condition (ASC)? One hypothesis holds that deficits arise from reduced fixation of the information-rich eye region. However, neurotypical individuals (NT) who prefer to fixate low on faces perform as well as NT individuals who fixate high (Mehoudar et al., 2014). Further, individuals tend to recognize faces best near their personal preferred fixation location (Peterson & Eckstein, 2013), suggesting mutual retinotopic tuning of the eye movement and face processing systems. Here, we tested the hypothesis that impaired face recognition in ASC is associated not with lower face fixations per se, but with suboptimal tuning to an individual's preferred fixation. We measured eye movements, face memory ability, and face perception ability in 16 ASC and 15 NT control subjects. We found that ASC participants had: 1) a trend toward lower preferred fixations (p=.07), 2) large face memory deficits (CFMT, p< .001; Celebrity Identification, p=.01), and 3) mild deficits in a successive same/different face perception task while fixating either the eyes or mouth (p=.03). Surprisingly, higher preferred fixations were associated with larger recognition deficits in ASC but not NT participants. The difference in perceptual discrimination performance between individuals' best and worst fixation locations was not significantly different between groups, suggesting the presence of retinotopic tuning in ASC. Critically, face perception performance was better when faces were presented closer to an individual's preferred fixation location for NT but not ASC participants (p=.008). The absence of a systematic relationship between preferred fixations and position-dependent performance might suggest a failure to develop typical mutual tuning of the eye movement and face recognition systems in ASC. Alternatively, lab measurements of preferred face fixation in ASC participants may not accurately reflect their real-world looking behavior.

Acknowledgement: This material is based upon work supported by the Center for Brains, Minds and Machines (CBMM), funded by NSF STC award CCF-1231216.

41.16, 9:30 am **Reduced neural sensitivity for implicit individual face discrimination in autism** Sofie Vettori[1,3](Sofie.vettori@kuleuven.be), Milena Dzhelyova[2], Stephanie Van der Donck[1,3], Corentin Jacques[2], Jean Steyaert[1,3], Bruno Rossion[2], Bart Boets[1,3]; [1]Center for Developmental Psychiatry, Department of Neurosciences, KU Leuven, Belgium, [2]Institute of Research in Psychological Science, Institute of Neuroscience, University of Louvain, Belgium, [3]Leuven Autism Research (LAuRes), KU Leuven, Leuven, Belgium

Fluently recognizing faces is crucial for social interactions. Impaired and atypical face processing have often been postulated as key deficits in autism spectrum disorders (ASD). Despite the great amount of research on face processing in ASD it is still unclear which processes are impaired. This is partly due to overreliance on explicit face processing tasks, which may give an incomplete estimate of spontaneous face processing abilities in ASD. To address this limitation, we apply an innovative scalp electroencephalography approach combined with fast periodic visual stimulation (FPVS). Groups of typically developing (TD) boys (N=23) and boys with ASD (N=23) were presented with images at the fast periodic rate of 6 Hz. In experiment 1, face images were inserted every 5th stimulus (i.e. at 6/5 = 1.2 Hz, reflecting face categorization) among non-face object images. In experiment 2, the same face identity is presented at 6 Hz and a different identity appears every 1.2 Hz (reflecting face identity discrimination). Amplitude and scalp distribution of the base response to visual stimulation (6 Hz) were similar for boys with ASD and TD boys, indicating equal attention to the images presented on the screen. Furthermore, both groups show similar face-categorization responses (1.2 Hz in experiment 1) indicating that both groups fluently detect brief and periodic appearances of faces within a range of widely variable objects. However, in experiment 2 responses to brief changes in identity were much smaller for ASD than TD boys when faces were presented upright, while no group difference was found when faces were inverted. This demonstrates reduced sensitivity to individual faces in boys with ASD. We conclude that within a few minutes of recording time, we are able to pinpoint and quantify a specific impairment in implicit individualization of faces in individuals with ASD

Temporal Processing

Monday, May 21, 8:15 - 9:45 am, Talk Room 2

Moderator: David Alais

41.21, 8:15 am **Differential recalibrations of perception and decision underlying the central tendency of time perception** Saya Kashiwakura[1](kashiwakura.saya@gmail.com), Isamu Motoyoshi[2]; [1]Department of Integrated Sciences, The University of Tokyo, [2]Department of Life Sciences, The University of Tokyo

Our perception of time is known to systematically regress toward the mean of recent stimulus distribution. This phenomenon, known as central tendency, has been viewed as a product of assimilative recalibration to preceding stimuli in order to improve the overall performance of timing behavior. Here, however, we show that central tendency is a consequence of assimilative recalibration to past decisions rather than to past stimuli. In our psychophysical procedure, we measured the apparent durations of static sinusoidal gratings (1.0 c/deg) with various durations (0.2-0.9 sec) by means of a reproduction method (N=10). Using multiple regression analysis, we calculated the impact of preceding stimulus duration (Ws) and preceding reproduced duration (Wr) upon the response error in the current trial. Analysis showed that current response is strongly assimilated to preceding responses (Wr= 0.42; p< .0001) and contrasted from preceding stimuli (Ws= -0.25; p< .0001). The relative amount of assimilation and repulsion was well correlated with the amount of central tendency in individual observers, and the effect of a previous trial on current-trial bias decreased with inter-trial distance regardless of bias direction. Similar patterns of results were obtained if observers reproduced duration as indicated by a digit figure (0.2-0.9) that was shown with a fixed duration (0.7 sec), thereby suggesting that the repulsive component is unlikely to be a product of adaptation to physical stimulus duration. In an additional experiment, we found no clear evidence for such two distinct effects in the serial dependence of orientation perception which has been known for exhibiting an assimilative effect from preceding stimuli. These results suggest that our perceptual decision of event time is continually adjusted via two distinct adaptive processes: assimilative recalibration which retains consistency with past decisions (Bayesian) and repulsive recalibration which emphasizes the difference from past sensory inputs (anti-Bayesian).

Acknowledgement: JSPS KAKENHI JP16H01499 and JP15H03461

41.22, 8:30 am **When a visual event is perceived depends on where it is presented** Ljubica Jovanovic[1](lj.m.jovanovic@gmail.com), Pascal Mamassian[1]; [1]Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, PSL Research University, CNRS, 75005 Paris, France

Perceiving when an event occurs is important to properly act on it. The speed of visual processing increases with stimulus eccentricity (Carrasco et al., 2003), and perceived duration of visual events is contracted in the periphery (Aedo-Jury & Pins, 2010). Here, we investigated whether when an event is perceived depends on eccentricity. Participants were initially familiarized with a fixed interval duration by watching the hand of a clock rotating at a constant speed, making one full revolution in 2 seconds. In the main part of the experiment, the hand was removed and a small disc was briefly flashed at a random time within the interval duration. Participants used a cursor to indicate the location where the hand would have been at the time of the flash. In different blocks of trials, the discs were presented at different eccentricities from 0° to 36° (in 5 logarithmically equally spaced steps). To minimize attentional redirection to one hemifield, two stimuli were simultaneously presented on either side of

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fixation. The outline of the clock was either presented or omitted during the familiarisation and test phases. In a subsequent experiment, stimulus size was scaled according to a cortical magnification factor (Duncan & Boynton, 2003). Events were perceived earlier when they were presented in the periphery rather than at fixation. A bias of around 100 msec was present for stimuli close to the location of the response probe (the outline of the clock and the tip of its hand). In addition, there was also a smaller bias to report events earlier for larger eccentricities. Scaling the size of the stimuli did not reduce the biases. In summary, perceiving when an event occurs depends on how far it is in the periphery and where it is relative to objects we intend to act on.

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41.23, 8:45 am **Interhemispheric visual temporal order adaptation** Zhimin Chen[1](mandy_chen@berkeley.edu), Ikuya Murakami[2], David Whitney[1,3]; [1]Department of Psychology, University of California, Berkeley, [2]Department of Psychology, the University of Tokyo, [3]Vision Science Program and Helen Wills Neuroscience Institute, University of California, Berkeley

Perceiving the relative timing of visual events across the visual field is important for temporal grouping, motion perception, and scene recognition. However, a basic challenge to registering the synchrony of events across visual space is that information from the left and right halves of the visual field is initially processed separately in different brain hemispheres. How then does the visual system register and maintain temporal relationships such that physically synchronous information across the visual hemifields appears synchronous? Here we show that the visual system dynamically recalibrates what counts as synchronous across the left and right hemifields. Observers adapted to a sequence of random dot fields flashing on and off continuously. The spatial locations of dots on the left and right sides were mirror-symmetric. The flashing dot onsets within each hemifield were the same in the "coherent condition", and randomized in the "incoherent condition" (which avoided strong long-range motion artifacts). In both conditions, a 100 ms lag was introduced in the temporal luminance modulation between corresponding dots in the left and right hemifields. We found a negative aftereffect in subsequent temporal order judgments in both conditions: after adapting to an asynchrony across the vertical meridian, physically synchronous test stimuli appeared asynchronous. A lag (~9% of the adapting delay) was required to null the illusory temporal asynchrony. This aftereffect was specific to adaptation across the vertical but not the horizontal meridian. We further replicated the aftereffect using complex stimuli such as movie clips and dynamic fractal patterns. Our results demonstrate that the visual system calibrates the apparent timing of events selectively across the left and right halves of visual space, revealing a specialized mechanism that could help binding visual features, perceiving global patterns (e.g. symmetry), and maintaining the appearance of synchronous visual stimulation across visual space after blinks and eye movements.

41.24, 9:00 am **Reverse Radial Bias: Temporal Orientation Bias Compensation in Early Visual Areas Revealed by MEG** Huining Wu[1](aldyszhao@live.cn), Ikegaya Yuji[2,3], Hiroshi Ban[1,3]; [1]Graduate School of Frontier Biosciences, Osaka University, Japan., [2]Graduate School of Pharmaceutical Sciences, The University of Tokyo, Japan, [3]Center for Information and Neural Networks (CiNet), NICT, Japan

Human visual system is organized sophisticatedly but it is also known that it has some response biases (e.g. color sensitivity, orientation selectivity) depending on locations of the visual field. Nevertheless, we can perceive an isotropic visual world without notifying any selectivity biases of the underlying neural responses. Therefore, a long-standing question is how our visual system compensates the visual feature selectivity anisotropies. Here, using human MEG measurements (Elekta Neuromag 360ch, 1000 Hz, N=12) and a machine learning classification (a linear SVM) technique, we explored a temporal compensation mechanism of orientation selectivity bias (aka, Radial Bias) in early visual areas. Specifically, we measured cortical responses for -45 and 45 deg gratings and visualized the dynamic changes of the orientation selectivity in each of retinotopic cortical positions during and after the stimulus on/offsets. The two orientations could be discriminated (90% accuracy) at 100 ms after the stimulus onset. Furthermore, the orientation selectivity in V1-V3, computed from SVM classifier weights, followed the presumed radial bias preference in each of retinotopic locations. However, interestingly, we found the reversal of the radial orientation bias 120 ms after the stimulus offsets, which may suggest a temporal neural compensation mechanism for the non-preferred tangential orientations. Follow-up analysis showed that the reversal was more likely to come from the temporal alteration of neural selectivity rather than the spatial response pattern shift. To explore a functional meaning of the reverse radial bias, we run additional psychophysics to measure orientation sensitivity thresholds in the reverse period and found that the orientation detection inefficiency corresponding to the radial bias was recovered exactly in the reversal period. Taken together, those findings indicate that our visual system compensates the neural selectivity bias temporally, as well as spatially, to capture transient changes of objects seen in the dynamic visual world.

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41.25, 9:15 am **Convolutional recurrent neural network models of dynamics in higher visual cortex** Aran Nayebi[1](anayebi@stanford.edu), Jonas Kubilius[2], Daniel Bear[1], Surya Ganguli[1], James J DiCarlo[2], Daniel L K Yamins[1]; [1]Stanford University, [2]Massachusetts Institute of Technology

Neurons in the ventral visual pathway exhibit behaviorally relevant temporal dynamics during image viewing. However, the most accurate existing computational models of this system are feedforward hierarchical convolutional neural networks (HCNNs), which capture neurons' time-averaged responses, but do not account well for their complex temporal trajectories. Here we show that HCNNs augmented with both local and global recurrent connections are quantitatively accurate models of dynamics in higher visual cortex. We began with a five-layer HCNN that achieved state-of-the-art predictions of temporally-averaged visual responses in macaque V4 and IT neurons. To model within-area dynamics, we replaced units in each layer with one of several local recurrent circuit motifs, including simple Recurrent Neural Networks (RNNs), Gated Recurrent Units (GRUs), and Long Short-Term Memory (LSTM) units. We also included combinations of global feedback connections, in which outputs of later convolutional layers were added to inputs of earlier layers. Using backpropagation through time, these new parameters were optimized to predict V4 and IT neural response patterns. Finally, we tested these networks' ability to predict responses on held-out images and neurons not used for model optimization. We found that the best network structure led to substantial improvements over the feedforward baseline, explaining close to 100% of the explainable variance in V4 neurons and above 75% in IT neurons on average across time points. This network made use of gated local recurrence, with LSTMs and GRUs proving superior to simple RNNs. Furthermore, the presence of specific global feedback connections in this network was critical for best predicting V4 neuron dynamics. In summary, we have developed a deep recurrent neural network architecture that accurately captures temporal dynamics in several ventral cortical areas, opening the door to more detailed computational study of the circuit structures underlying complex visual behaviors.

41.26, 9:30 am **Information sampling and processing during visual recognition** Laurent Caplette[1](laurent.caplette@umontreal.ca), Karim Jerbi[1], Frédéric Gosselin[1]; [1]Department of Psychology, University of Montreal

Visual recognition is a phenomenon that seems to occur almost instantaneously. However, this is just an impression: not only does it require hundreds of milliseconds of processing, but information from the world must also be sampled during tens of milliseconds. This means that brain activity related to the recognition of an object is in fact composed of the brain responses to information sampled in different time windows. Furthermore, we can expect activity in response to different time windows to be different, partly because different features are attended and used at different moments during recognition, and because information perceived earlier must be maintained longer to be integrated with information perceived later. In this study, we aimed to decompose brain activity according to the sampling moment of information. To do so, we randomly sampled the main face features across 200ms on each trial while subjects performed a gender or expression recognition task and while their EEG

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activity was recorded. We then reverse correlated EEG amplitude in occipito-temporal sensors at all time points with information presented in different time windows: this allowed us to uncover the processing time course of information sampled at specific moments. We observed that processing was significantly different across presentation moments at several latencies and that the time windows leading to high activity correlated with the time windows leading to accurate responses. We also found that presentation moment modulated the durations of the P1 and P3 components. Importantly, these differences were not the same across tasks, indicating that their origin is partly top-down. In summary, we uncovered for the first time the processing of information sampled at different moments during recognition. We showed that sampling moment modulates the processing of information in more than one way, and that this modulation is partly related to top-down routines of information extraction

3D Perception: Objects and surfaces

Monday, May 21, 10:45 am - 12:15 pm, Talk Room 1

Moderator: Erich Graf

42.11, 10:45 am **Monocular and binocular recovery of 3D symmetrical and near-symmetrical shapes** Vijai Thottathil Jayadevan[1], Tadamasa Sawada[2], Edward Delp[1], Zygmunt Pizlo[3]; [1]School of Electrical and Computer Engineering, Purdue University-West Lafayette, [2]School of Psychology, National Research University Higher School of Economics, [3]Department of Cognitive Sciences, University of California-Irvine

Monocular and binocular recovery of 3D symmetrical and near-symmetrical shapes Vijai Jayadevan, Tadamasa Sawada, Edward Delp and Zygmunt Pizlo Our prior work demonstrated that perception of 3D symmetrical shapes can be explained by a cost function that combines a priori constraints such as symmetry and compactness with binocular depth-order information. In this study we show that a cost function containing these terms can explain perception of near-symmetrical shapes, as well. In the experiment, performed in a virtual reality environment using Oculus Rift, the subject adjusted 3 parameters of a rotating 3D shape to match the percept of a stationary reference shape. The reference shape was either mirror-symmetrical or asymmetrical. The asymmetrical shapes were produced by applying an affine transformation to the symmetrical shape. Ninety objects of varying degree of symmetry and compactness were used in the experiment. Three subjects were tested. The subject adjusted 3 parameters representing all 3D affine transformations of the 3D shape that keep the 2D cyclopean orthographic image unchanged. These parameters included a uniform stretch and compression along the depth direction. Our results show that binocular perception of 3D symmetrical shapes is veridical. In particular, there is no systematic under- or over-estimation of depth. Binocular perception of near-symmetrical shapes is less veridical – the percept is biased by the symmetry and compactness constraints. Monocular perception of symmetrical and near symmetrical shapes can be explained by symmetry and compactness priors. Individual differences are minimal, if present at all, in monocular viewing. Binocular viewing shows appreciable individual differences in the case of asymmetrical shapes. These individual differences correspond to the relative weights of the symmetry, compactness and binocular depth-order terms in the cost function.

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42.12, 11:00 am **Changes in Viewing Distance Produce Systematic Distortions of the Apparent 3D Shapes of Symmetric Polyhedra** Ying Yu[1](yu.1416@osu.edu), James T Todd[1], Alexander A Petrov[1]; [1]Department of Psychology, The Ohio State University

Prior studies have shown that the perceived depth from binocular disparity becomes increasingly compressed as the viewing distance increases. Because of this perceptual distortion, two objects with the same 3D shape are predicted to have different apparent shapes when viewed simultaneously from non-matching distances: The far object should appear compressed in depth relative to the near object. Method: To test these hypotheses, computer-generated stereoscopic images of mirror-symmetric 3D polyhedra, similar to the stimuli of Li et al. (2011, doi:10.1167/11.4.11), were viewed binocularly through shutter glasses. On each trial, two such polyhedra were presented side by side against a black background on a LCD monitor, and each of these objects was positioned independently at a viewing distance of 100 cm (“near”) or 200 cm (“far”). The stimuli differed in size and were rendered in the same 3D orientation relative to the cyclopean eye of the observer. The reference polyhedron had a fixed 3D shape. The test object was scaled in depth relative to the reference, and this scaling could be adjusted by observers. The task on each trial was to adjust the test object so that it appeared to have the same 3D shape as the reference. Results: The group-averaged Z-scaling was approximately 30% higher in the far-test/near-reference condition than in the near-test/far-reference condition. By contrast, the Z-scaling was approximately equal in the two equidistant conditions. This indicates equivalent perceptual distortions for both objects at a common distance. Moreover, the scaling in the equidistant conditions was approximately halfway between the adjustments in the two non-equidistant conditions, as predicted. Overall, these results suggest that 3D shape perception is systematically distorted even for compact symmetric polyhedral objects in a shape matching task, which contrasts sharply with the theoretical predictions of Li et al. (2011).

42.13, 11:15 am **Which parts of a shaded image relate invariably to which parts of a 3D shape?** Benjamin S Kunsberg[1](bkunsberg@gmail.com), Steven W Zucker[2]; [1]Division of Applied Mathematics, Brown University, [2]Department of Computer Science, Yale University

Although it is commonly assumed that there are stable image features that relate directly to parts of a surface, this question is subtle because it involves an ill-posed inverse problem. In particular, what does one mean by a `stable feature of the image' or a `part of the surface'? What does one mean by a `stable relationship'? We adopt the concept of critical contours and the Morse Smale (MS) complex to answer these questions. The MS complex (similar to a generalized segmentation) considers topological properties of the image gradient to construct a qualitative representation of the image. We use this to analyze global and topological properties of the image and to relate them to parts of the surface rigorously. We have shown previously (arxiv.org/abs/1705.07329) that critical contours, particular curves in the MS complex, are remarkably stable in the image as the lighting changes. We now study the 3D surface shape properties that relate 1-to-1 with the segmentation regions. We explore the important case where the critical contours define a complete segmentation. This can happen in two ways. First, all the critical contours can join the boundary. Then one can generically conclude that the segmented surface regions are either ridges or monotonic. Second, when critical contours form closed cycles in the MS complex, one can generically conclude that the interior surface regions are bumps or valleys. Thus, these regions of the image relate directly to Morse properties of the surface. Strong independence properties among the different segmentation regions follow from the MS segmentation. Specifically, the model predicts that some segmented regions can be perceptually bistable, with convex/concave switches occurring within an otherwise stable surround. Novel examples of such effects support the model experimentally.

42.14, 11:30 am **Binocular depth cues break camouflage** Wendy J Adams[1](w.adams@soton.ac.uk), Matt Anderson[1], Erich W Graf[1]; [1]Department of Psychology, University of Southampton

Many species employ camouflage to disguise their true shape. One type of disruptive colouration, ‘edge enhancement’, can be used to create salient, illusory depth edges within an animal’s body, whilst their true outline blends into the background. Binocular vision could provide a critical advantage in the arms race between perception and camouflage: binocular disparities reveal the true depth structure of the scene. However, little is known about whether stereopsis can ‘break’ camouflage. Human observers were asked to locate snake targets embedded in leafy backgrounds. We analysed performance (response time) as a function of edge enhancement, illumination, and the availability of binocular depth cues. We confirmed that edge enhancement contributes to effective camouflage: observers were slower to find snakes whose patterning contained ‘fake’ depth edges. Importantly, however, this effect disappeared when binocular depth cues were available. Illumination also affected snake detection: when scenes were rendered under directional illumination, such that both the leaves and snake produced strong cast shadows, snake targets were localised more quickly than in scenes rendered under ambient illumination. This facilitatory effect was reduced, but still signifi-

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cant under stereoscopic viewing. In summary, our data suggest that both binocular disparity and directional illumination improve detection by providing information about the true 3D structure of a scene. Moreover, the strong interaction between disparity and edge enhancement suggests that binocular vision has a critical role in breaking camouflage – to ensure that misleading pictorial depth cues, which suggest the presence of depth discontinuities, are overruled.

42.15, 11:45 am **Half-occlusion boundary detectors in computational stereo vision** Jialiang Wang[1](jialiangwang@g.harvard.edu), Daniel Glasner[2], Todd Zickler[1]; [1]Harvard University, [2]AiCure

There are two sources of depth information in a stereo pair. One is the correlation signal from smooth surface regions that are visible to both eyes, which provides depth information via triangulation. The other is the decorrelation signal near occluding contours, which provides information about the locations and amplitudes of depth discontinuities by the half-occlusions they induce. A variety of perceptual stimuli have convincingly demonstrated the active roles of both signals in stereopsis. In computational vision, there has been less progress in using the decorrelation signal. For example, one common approach is a "left-right consistency check," which uses correlation to estimate two separate depth maps from the left and right viewpoints, and then reasons about half-occlusions based on where these two depth maps disagree. This strategy can succeed in practice, but it breaks down and is entirely inconsistent with human perception when applied to stimuli with limited correlation cues (e.g., those of Nakayama and Shimojo [1990]). We have developed a computational approach that uses decorrelation more effectively. The key ideas are to incorporate local detectors for the half-occlusion boundaries within the visual field, and to combine the responses from these detectors with correlation information using a piecewise-smooth representation of disparity. Our half-occlusion boundary detectors are based on the spatial gradient of the correlation signal, and they are inspired by the binocular-monocular receptive fields proposed by Anderson and Nakayama [1994]. Our approach is formulated as energy minimization along 1D epipolar scanlines, using an objective function that can be globally optimized by dynamic programming. We tested the algorithm on a collection of twelve perceptual stimuli that have weak correlation cues. We found that the disparity profiles that minimize our energy match human perception. We also found that our use of decorrelation cues improves disparity accuracy in half-occluded regions of natural images.

42.16, 12:00 pm **Use of continuous 3D target-tracking in VR to measure response latency to changes in depth** Benjamin T. Backus[1](ben@seevividly.com), James J. Blaha[1], Lawrence K. Cormack[2,3,4], Kathryn L. Bonnen[2,3]; [1]Vivid Vision Labs, Vivid Vision, Inc., [2]Center for Perceptual Systems, UT Austin, [3]Inst. for Neuroscience, UT Austin, [4]Dept. Psychology, UT Austin

Stereoscopic depth perception can be as fast as the perception of luminance (Caziot et al 2015 JEP:HPP) and disparity perturbations have fast effects on reaching (Greenwald, Knill & Saunders 2005 Vis Res). Yet stereo can also be slow: depth was tracked much more slowly than horizontal or vertical position by the eyes (Mulligan, Stevenson & Cormack 2013 Hum Vis and Electronic Imaging) or hands (Bonnen, Huk & Cormack 2015 J Neurophys), and modulation in depth is not visible above 5 to 10 Hz (Kane, Guan & Banks, 2014, J Neurosci). What accounts for these extraordinary discrepancies? We hypothesized that stereoscopic depth is estimated very quickly when an object first appears, but that as it persists, its stereoscopic depth is integrated over time with the long time constants measured previously. We employed continuous target-tracking to measure latency in the response to changes of position in 3D. Non-stereo depth cues were not informative. Targets followed a 120-sec random walk in 3D (normally distributed steps in x, y, and z, SD 3mm, 90 Hz). Large discrete jumps were introduced randomly every 1-4 sec. The purpose of the jump was to re-start depth integration, so we predicted that latencies would be shorter for jumps than during random-walk motion. We did not confirm the hypothesis: instead, some participants were very fast to track depth, as fast as for horizontal or vertical (peak correlation between stimulus and tracker at 220-270 ms), while others were selectively slow for depth (450 ms or more). These differences were similar for continuous tracking and jumps within an individual. However, the instructions mattered: when asked to be accurate in depth, latencies decreased for depth tracking. We conclude that the use of disparity to track targets in depth is not universally slow.

Attention: Temporal, tracking and divided

Monday, May 21, 10:45 am - 12:15 pm, Talk Room 2

Moderator: Yuhong Jiang

42.21, 10:45 am **Flanking Distractors are Recognized and Suppressed Before the Target is Identified** Ricardo Max[1](ricardo.max@nyu.edu), Yehoshua Tsal[2], Marisa Carrasco[1]; [1]New York University, [2]Tel Aviv University

Introduction. In typical flanker tasks, responses to a target (with two alternative identities) that is flanked by incongruent distractors (bearing the alternative target identity) are slower compared to neutral distractors. We separately assessed the processing timecourses of incongruent and neutral distractors by conducting speed-accuracy trade-off (SAT) analyses on six experiments employing the mutations protocol (Max & Tsal, 2015). Methods. While the target remained unchanged until response, distractors mutated once, at a random time within 100 ms following stimulus onset. There were three trial types: incongruent distractors mutated to neutral; vice versa; or neutral to neutral (control trials). Comparisons among trial types within each mutation time, revealed the time-window of information extraction from distractors. Mutations effects. Incongruent distractors were suppressed 29 ms later than neutral distractors (69 vs 40 ms after onset). Targets in incongruent displays were identified 41 ms later than in neutral displays (104 vs 63 ms), which delayed responses to incongruent displays by 22 ms, compared to neutral displays (429 vs 407 ms). SAT analyses. For all trials on which distractors mutated during the initial 33 ms after onset, responses executed slower than 220 ms resulted in performance above chance level (50%). For trials mutated later than 33 ms, responses executed faster than 140 ms remained at chance level. All responses slower than 140 ms on neutral-to-neutral and neutral-to-incongruent trials rendered above chance performance. Yet, surprisingly, on incongruent-to-neutral trials, responses executed between 140 and 220 ms plunged significantly below chance (32%, p=.003). In sum, when incongruent distractors were presented during at least the initial 33 ms, fast responses reflected the distractors' identity rather than the target's. Conclusions. Challenging conventional assumptions, these results suggest that immediately following stimulus onset, most resources are initially invested into recognizing and suppressing distractors. As distractors become suppressed, resources become increasingly available for target identification.

42.22, 11:00 am **Characteristics of sustaining attention in a gradual-onset continuous performance task** Jihyang Jun[1](junxx082@umn.edu), Roger Remington[1,2,3], Wilma Koutstaal[1], Yuhong V. Jiang[1]; [1]Department of Psychology, University of Minnesota, Twin cities, [2]Center for Cognitive Sciences, University of Minnesota, Twin cities, [3]School of Psychology, University of Queensland, Brisbane

Continuous performance tasks are frequently associated with vigilance decrement, particularly when target events are rare and when the observer has been on the task for 30 minutes or longer. Here we characterized the time course of performance decrement that happens more rapidly. Using the gradual-onset continuous performance task (the gradCPT; Esterman, Noonan, Rosenberg, & DeGutis, 2013), we presented participants with a long sequence of scenes that gradually faded in and out. Participants pressed a button as soon as they detected scenes in one category (e.g., cities) and ignored scenes in another category (e.g., mountains). We manipulated the novelty of stimuli, repetitiveness of motor response, and the prevalence rate of the target stimuli. Replicating recent findings using the gradCPT, we found that the performance sensitivity(d') declined moderately within and across multiple 8-minute-long blocks. This decline was not restricted to situations where target events were rare and stimuli were repetitive. Repetitive motor responses had a large detrimental effect on the overall d', but did not significantly modulate performance decrement. The rapidity of performance decrement and its insensitivity to target prevalence distinguish this type of performance decrement from the more traditional, slower-to-emerge vigilance decrement.

42.23, 11:15 am **Attention explores space at the theta frequency**

Laura Dugué[1](laura.dugue@gmail.com), Mehdi Senoussi[2], James C Moreland[3], Niko A Busch[4]; [1]Laboratoire Psychologie de la Perception, Université Paris Descartes, Paris, France, [2]Laboratoire des Facteurs Humains, ISAE-Supaéro, Toulouse, France, [3]University of Washington, Seattle WA, USA, [4]Institute of Experimental Psychology, Westfälische Wilhelms-Universität, Münster, Germany

Covert, voluntary attention enhances visual processing at the attended location, in the absence of eye movements. Attention reorienting, i.e. the displacement of the attention focus in space, allows processing at other locations, critical in an ever-changing environment. Recently, using TMS, Dugué et al. (2016) showed that attentional reorienting periodically involves V1/V2 at the theta frequency. In the current experiment, we used a psychophysics protocol to measure attentional sampling across space and time during reorienting. We manipulated voluntary attention using a central cue. Participants performed a 2-AFC orientation discrimination task in which they had to report the orientation of a target grating (clockwise or counter-clockwise relative to vertical). Trials could be valid, when the target is at the attended location (75% of the trials) or invalid, when the target is at the unattended location (25% of the trials). Additionally, two probes (Landolt C's squares or rectangles; 12 possible probes) were then flashed at a variable delay after stimulus offset. Performance in reporting the probes was used to infer attentional deployment to those locations (probability estimation method, see Dugué et al., 2015b and 2017b). By solving a second-degree equation, we determined the probability of probe report at the most (P1) and least (P2) attended locations on a given trial. We show that, in both valid and invalid conditions, P1 was higher than P2, indicating that processing was non-uniformly distributed across locations. Critically, this deployment was periodically modulated over time at ~6Hz (theta), only in the invalid condition, i.e. when attention needs to be reoriented. Finally, we show the analysis method of Dugué et al. (2015b; 2017b) to be appropriate and sufficiently powered by replicating the results using the obtained variability in Monte Carlo simulations. Together, these results suggest that voluntary attention reorients periodically in space and in time, at the theta frequency.

42.24, 11:30 am **Tracking of moving players in soccer: Multiple object tracking in real-life environment**

Lauri O Oksama[1,2](loksama@utu.fi), Teemu Leino[3], Jukka Hyönä[3]; [1]Academy of Finland, [2]National Defence University, [3]University of Turku

Multiple object tracking (MOT) has been extensively studied in the laboratory. However, the relevance of this task to performance in the real-life environments is unknown. Here we examine whether the performance in laboratory tasks of MOT with identical objects (Pylyshyn & Storm, 1988) and that of multiple identity tracking (MIT) with distinct objects (Oksama & Hyönä, 2004) correlate with a real-life tracking performance, that is making a passing decision in soccer. Furthermore, we study how much information can be extracted in dynamic real-life environments. It is possible that previous laboratory results with artificial stimuli and novice participants underestimate the capacity in real-life tracking. It is conceivable that soccer experts can track players better than novices. To study these questions, we devised a task battery including a video-based soccer task measuring passing accuracy, a video-based realistic MIT task, a laboratory MIT task (moving faces of FC Barcelona players) and two laboratory MOT tasks with medium and fast speed. The task battery was presented to 27 experienced soccer players and 22 novices. Regression analyses showed that the MIT tasks proved to be significant predictors of the accuracy in making passing decisions, whereas, contrary to our expectations, MOT tasks did not show any significant correlation with the passing task. Moreover, experts performed better than novices in the realistic MIT task; they were able to track more player information than novices. However, no expert – novice –differences were found in the MOT tasks. These results suggest that the cognitive ability needed in the MIT tasks resembles closely abilities needed in the real-life tracking tasks but such resemblance was not found with MOT. The results are consistent with our previous findings that MIT and MOT are performed by separate systems in terms of eye-movements and brain activity (Oksama & Hyönä, 2016; Nummenmaa, Oksama, Glerean, & Hyönä, 2017).

Acknowledgement: Academy of Finland

42.25, 11:45 am **Mapping glaucomatous visual fields during panoramic driving simulation**

David E Anderson[1](dendersn@gmail.com), Deepta Ghate[2,3], Sachin Kedar[1,2,3], Vikas Gulati[2,3], Madeleine Sharp[1], Matthew Rizzo[1]; [1]Department of Neurological Sciences, University of Nebraska Medical Center, [2]Department of Ophthalmology, University of Nebraska Medical Center, [3]Truhlsen Eye Institute, University of Nebraska Medical Center

Glaucoma is an optic neuropathy that impairs peripheral vision, increasing motor vehicle crash risk. Mechanisms underlying impaired driving in glaucoma demand further study. Here, we developed a novel driving simulator visual field (DSVF) task to study how glaucomatous visual field (VF) loss affects driving under naturalistic conditions. DSVF was completed in a dynamic panoramic driving simulator with 290-degree forward field of view. Stimulus size and retinal positions mirrored standard clinical perimetry (Humphrey Visual Field; HVF), facilitating cross-platform comparisons. We calculated global visual field index (VFI) to estimate proportion of VF unimpaired, similar to HVF (Bengtsson, 2008). We studied 13 glaucoma patients with VF impairment (VFI: 24-88% worse eye) and 10 comparisons without VF impairment (VFI: 99-100%). In Experiment 1, participants completed monocular DSVFs against a gray background while maintaining stable fixation. DSVF VFIs demonstrated high test-retest reliability (r>.98) and correctly mapped VF blind spots. VFI estimates between DSVF and HVF platforms correlated for left (r=.87) and right eye (r=.87) VFs. In Experiment 2, participants completed binocular DSVFs without fixation against a naturalistic background during three cognitive load conditions: (1) stationary; (2) simulated driving; (3) simulated driving while concurrently performing an auditory task (PASAT). Baseline binocular DSVF performance was also measured using a gray background to evaluate cognitive load effects. Consistent with previous studies (Park & Reed, 2015; Wall et al., 2004), we found load-dependent VFI reductions. Furthermore, VFI reductions were greater in glaucoma patients than controls during simulated driving (p< .05; Cohen's d=.98). In summary, DSVFs are a valid measure of VF loss when compared to standard clinical perimetry, and demonstrate load-dependent VF impairments during driving simulation. Importantly, glaucoma patients experienced greater VF impairment than controls during driving simulation. These results suggest attention impairments may affect safety critical tasks such as visual search in the periphery in glaucoma.

Acknowledgement: R01 AG017177

42.26, 12:00 pm **Anxious Anticipation Prolongs the Emotion-induced Blindness Effect**

Nadia Haddara[1,2](nhaddar1@binghamton.edu), Jonathan Ravid[1], Erica Miller[1], Molly O'Hagan[1], Chris Caracciolo[1], Ryan O'Rourke[1], Jourdan Pouliot[1], Stacey Davis[1], L. Jack Rhodes[1], Vladimir Miskovic[1,2]; [1]Department of Psychology, SUNY Binghamton, [2]Center for Affective Science, SUNY Binghamton

Emotionally arousing images produce a transient accuracy impairment for detecting neutral targets under conditions of stringent spatiotemporal competition (e.g., rapid serial visual presentation). This performance impairment has been termed emotion-induced blindness and previous studies have demonstrated that the magnitude and time course of this visual processing impairment is exaggerated in individuals with clinical anxiety disorders. Here, we tested whether the emotion-induced blindness effect can be modulated by anxious anticipation in a healthy sample of participants. We embedded naturalistic scenes in a 10 Hz rapid serial visual presentation (RSVP) stream, and varied the hedonic content of distractor images (aversive or neutral) that preceded neutral targets by 200, 400 or 700 ms. Experiment 1 examined the magnitude and time course of the emotion-induced blindness effect under typical conditions (no anxiety induction). We found that aversive distractors induced a temporary visual performance decrement at the 200-lag that was fully recovered by the 400-lag. In Experiment 2, participants performed the same RSVP task while under continuous threat of unpredictable electric shock. We found that the threat of unpredictable electric shock prolonged the duration of the emotion-induced blindness effect out to 400 and 700 ms, without affecting the overall magnitude of impairment. In Experiment 3, we tested the robustness of these findings by manipulating anxious anticipation within subjects over a two-day session. We replicated the effect of anxiety on emotion-induced blindness, which persisted at the 400-lag under the threat of shock compared to a safe (no shock) condition.

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The effect of anxiety occurred despite observed practice effects, suggesting that anxiety impacts task performance by delaying the amount of time that is necessary to recover from aversive distractor stimuli without directly enhancing the magnitude of visual impairment.

Monday Morning Posters

Scene Perception: Mechanisms and models

Monday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

43.301 **Neural representation of the intuitive physical dimension of mass** Sarah E Schwettmann[1](schwett@mit.edu), Jason Fischer[2], Joshua B. Tenenbaum[1], Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Sciences, Massachusetts Institute of Technology, [2]Department of Psychological & Brain Sciences, Johns Hopkins

Engaging with the world requires a model of its physical structure and dynamics – how objects rest on and support each other, how much force would be required to move them, and how they behave when they fall, roll, or collide. Humans demonstrate remarkable ability to infer the physical properties of objects and predict physical events in dynamic scenes, yet little is known about the neural representations underlying intuitive physical judgments. Recent behavioral and computational studies of human physical scene understanding suggest that people's judgments can be modeled as probabilistic simulations of a mental physics engine akin to 3D physics engines used in computer simulations and video games. Physics engines share a common structure: enduring properties of objects such as mass and friction serve as inputs to models of world dynamics. We ask whether such a physics engine exists in the brain, and begin by searching for neural representations of fundamental physical variables that define objects. Here, using event-related fMRI and multivariate pattern classification techniques, we tested whether candidate functional regions of interest (fROIs) for a neural physics engine (Fischer et al., 2016) represent object mass. We obtained significant mass decoding in 12 out of 12 subjects from multivoxel activity within these fROIs while adult subjects watched videos of objects interacting in various physical scenarios: splashing into water, being blown by a hairdryer, and falling onto a soft surface. Critically, these mass representations generalize across scenarios, and were decoded during both a mass judgment task and an orthogonal task (a color judgment on the same stimuli). These results suggest that candidate fROIs for a neural physics engine represent situation-invariant physical information that may serve as input to a generalized engine for physical simulation. Ongoing work investigates what other physical information is represented, and the generality and automaticity of these representations.

43.302 **Scaling Up Neural Datasets: A public fMRI dataset of 5000 scenes** Nai Chen Chang[1](nchang1@cs.cmu.edu), Elissa Aminoff[2], John Pyles[3,4], Michael Tarr[3,4], Abhinav Gupta[1]; [1]Robotics Institute, Carnegie Mellon University, [2]Department of Psychology, Fordham University, [3]Department of Psychology, Carnegie Mellon University, [4]Center for the Neural Basis of Cognition, Carnegie Mellon University

Vision science - and particularly machine vision - is being revolutionized by large-scale datasets. State-of-the-art artificial vision models critically depend on large-scale datasets to achieve high performance. In contrast, although large-scale learning models (e.g., deep learning models such as Alexnet) have been applied to human neuroimaging data, the image datasets used on neural studies often rely on significantly fewer images - typically a few hundred due to time-constrained experimental procedures. The small size of these datasets also translates to a limited diversity of used images covered in image space. The lack of image feature diversity inherently limits the degree to which neural data can act as supervisory signals and our ability to compare model and measured neural representations. Here we dramatically increase the image dataset size deployed in an fMRI study of visual scene processing, scaling the number of images by over an order of magnitude relative to most earlier studies: over 5,000 discrete image stimuli were presented to each of four participants. We believe this boost in dataset size will better connect the field of computer vision to human neuroscience. To further enhance this connection and increase image space overlap with computer vision datasets, we include images from two standard artificial learning datasets in our stimuli: 2,000 images from COCO; 2 images per category from ImageNet (~2,000). Also included are 1,000 hand-curated indoor and outdoor scene images from 250 categories. These three image collections cover a wide variety of image types, thereby enabling fine-grained exploration into visual representations ranging from natural scenes to object categories to human interactions. The scale advantage of our dataset and the use of a slow event-related design enables, for the first time, joint computer vision and fMRI analyses that span a significant and diverse region of image space using high-performing models.

Acknowledgement: NSF # 1439237 : CompCog: Human Scene Processing Characterized by Computationally-derived Scene Primitives.

43.303 **Early electrophysiological markers of navigational affordances in scenes** Assaf Harel[1](assaf.harel@wright.edu), Jeffrey D Nador[1], Michael F Bonner[2], Russell A Epstein[2]; [1]Department of Psychology, Wright State University, [2]Department of Psychology, University of Pennsylvania

Recent work has demonstrated that information about the structure and function of visual scenes is encoded in the brain by 220ms post-stimulus onset. For example, Harel et al. (2016) reported that diagnostic scene properties, such as spatial expanse (open vs. closed) and naturalness (manmade vs. naturalness), modulate the amplitude of early visual Event-Related Potentials (ERPs), particularly the P2. Given that open and closed scenes can be thought as two ends on a navigability continuum, we reasoned that these ERP markers might contain information about the number of pathways that afford movement in the local environment. To test this idea, we recorded ERPs from participants while they passively viewed computer-generated room scenes matched in visual complexity used in a previous fMRI study of navigability (Bonner & Epstein, 2017). By simply changing the number of doors (no-doors, one door, two doors, three doors) we were able to systematically control the number of movement paths in the scene, while keeping the overall size and shape of the environment constant. We found that rooms with no doors evoked a higher P2 response than rooms with three doors, analogous to the higher P2 amplitude to closed relative to open scenes previously reported. The P2 amplitude to rooms with one or two doors was higher than three-door rooms but lower than the response to no-door rooms. The parametric navigability effect on the ERP waveforms persisted following the P2 peak (around 250ms), lasting up until 650ms post-stimulus onset. Together, these results suggest that the perceived ease of navigation in a scene, as reflected by the number of potential pathways through it, is represented in both early and late stages of scene perception. This finding complements recent fMRI research showing that the occipital place area automatically encodes the structure of navigable space in visual scenes.

43.304 **Investigating the temporal dynamics of object-scene integration using MVPA: The role of the N300/N400 complex in object perception** Dejan Draschkow[1](draschkow@psych.uni-frankfurt.de), Edvard Heikel[2], Melissa L.-H. Võ[1], Christian Fiebach[2], Jona Sassenhagen[2]; [1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt, [2]Department of Psychology and Interdisciplinary Center for Neuroscience, Goethe University Frankfurt

Attributing meaning to diverse visual input is a core feature of human cognition. Typically investigated by violating certain environmental expectations and regularities (e.g., a toothbrush in the fridge), a late event-related negativity (N400) has not only been linked to the semantic processing of language, but also to objects and scenes. Incongruent object-scene relationships are additionally associated with an earlier negative deflection of the EEG signal between 250-350ms – often referred to as N300 – and hypothesized to reflect pre-semantic perceptual processes. We used multivariate pattern analysis (MVPA) to investigate whether these two components are truly separable or if the early object-scene integration activity (250-350ms) shares certain levels of processing with the late neural correlates of meaning processing (400-600ms). Forty participants were presented with semantic inconsistencies, in which an object was incongruent with a scene's meaning. Replicating previous findings, our manipulation produced significant N300 and N400 deflections in

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a standard ERP analysis. MVPA showed above chance classification of congruent vs. incongruent object-scene relationships during both the N300 and N400 time windows. To test to which degree similar neural patterns occur at different time points -–i.e., if neurocognitive patterns are shared between early and late components –, we used a time-generalized multivariate decoding procedure (King & Dehaene, 2014) where a classifier trained at one time point in a trial (e.g., during the N300 time window) is tested at every other time point (i.e., including the N400 time window). This analysis revealed above chance decoding performance for classifier trained during time points of the N300 component and tested during later time points of the N400. Our results show that neural patterns are shared between early and late processing during this complex of distinct ERP peaks – indicating that context processing interacts with early perceptual stages of object processing

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43.305 **Dynamic Construction of Feature-Based Representations for Perceptual Decisions in the Occipito-Ventral Pathway** Jiayu Zhan[1,2](j.zhan.1@research.gla.ac.uk), Robin Ince[1], Nicola Van Rijsbergen[1], Philippe Schyns[1,2]; [1]Institute of Neuroscience and Psychology, University of Glasgow, [2]School of Psychology, University of Glasgow

Current models of vision propose that the brain uses a multi-layered architecture to reduce the high dimensional input it receives (e.g. a street crowded with people and vehicles) to lower dimensional representations that support a variety of everyday categorization behaviors (e.g. perceiving "a happy Mary," on a "bus" in "New York City"). To explicitly study the reduction mechanisms from brain activity, on each experimental trial we used the Bubbles technique to randomly sample visual information from an ambiguous scene—i.e. Dali painting Slave Market with Disappearing Bust of Voltaire (see SuppFig A) — while simultaneously measuring the perceptual decisions (i.e. "the nuns," "Voltaire," "don't know") of 5 observers and their dynamic brain activity recorded with MEG. For each observer we first quantified the relationship between the random information samples and the perceptual decision across trials (2885-4145 per observer) with mutual information. This revealed the stimulus features that functionally link the painting to each perceptual decision—henceforth, the diagnostic features (see SuppFig A). A similar analysis performed on 12,000 MEG sources (between 0 and 400ms post-stimulus) revealed a consistent data reduction pattern in each observer: before 170ms, occipital cortex represents the diagnostic features of each perceptual decision but also other, nondiagnostic features; after 170ms, a reduction occurs at the juncture between occipital cortex and ventral regions whereby only diagnostic features remain represented in occipital and ventral cortex (SuppFig B). In ventral cortex, Diagnostic features reach the right fusiform gyrus around 140-170ms via a middle cluster of voxels associated with perceptual decisions. Diagnostic features then migrate to a second cluster, around 170-200ms, where we demonstrate, using information theoretic redundancy, that they form specific feature-based distributed representations that support perceptual decision behaviors (SuppFig C).

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43.306 **Transfer of Diagnostic Features from Occipital Cortex to right Fusiform Gyrus for Perceptual Decisions** Yaocong Duan[1,3](y.duan.1@research.gla.ac.uk), Jiayu Zhan[1,2], Robin Ince[1], Nicola van Rijsbergen[1], Philippe Schyns[1,2]; [1]Institute of Neuroscience and Psychology, University of Glasgow, [2]School of Psychology, College of Science and Engineering, University of Glasgow, [3]School of Engineering, College of Science and Engineering, University of Glasgow

Visual neuroscience aims to model the occipitoventral pathway as a hierarchically organised network of interconnected brain regions that process information to perceive and categorize complex visual scenes. Here, we investigated an important component of these mechanisms: the explicit transfer of features from their early coding in the occipital cortex to their later coding in the right fusiform (rFG) involved in higher-level processing. Five observers identified either "the Nuns" or "Voltaire" in Dali's ambiguous painting Slave Market with Disappearing Bust of Voltaire from visual information randomly sampled on each trial with Bubbles (see SuppFig A). Across trails (mean=3396, range 2885-4154), for each observer we quantified with Mutual Information (MI) the diagnostic features underlying each perceptual decision (see SuppFig A). A similar analysis performed on brain activity measured with MEG localized to 12773 sources, 0-400ms post-stimulus, revealed the spatio-temporal pattern of diagnostic feature coding in the occipitoventral pathway. We then explicitly tested diagnostic feature transfer from early sending sources in occipital cortex to later receiving sources in the rFG. According to the Weiner-Grainger framework, a casual transfer of a representation would occur if a diagnostic feature is represented equivalently (revealed with information theoretic temporal redundancy) in "Sender" at time t1, then at "Receiver" at a later time t2(but not at t1). Thus, for each receiving rFG source we selected the putative "sender" as the occipital cortex source with the highest coding of diagnostic feature (i.e. highest MI) prior (>10) to the peak coding of the receiver and computed feature transfer. Our results reveal a transfer of diagnostic features from occipital cortex to rFG (see SuppFig B and C). Here, we reconstructed a dynamic information proceeding network in the occipitoventral pathway that codes and transfer the specific features underlying perceptual decisions.

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43.307 **Mapping the neuroelectric state-space geometry of natural scenes** Bruce C Hansen[1](bchansen@colgate.edu), David J Field[2], Michelle R Greene[3], Cassady Olson[1], Vladimir Miskovic[4], L Jack Rhodes[4]; [1]Department of Psychology & Neuroscience Program, Colgate University, [2]Department of Psychology, Cornell University, [3]Neuroscience Program, Bates College, [4]Department of Psychology, Binghamton University

The evoked potentials of the human visual system are known to carry information regarding the images that produce them. However, the relationship between image statistics and macro-scale neuronal responses remains unclear. Here, we approach the problem by mapping the state-space geometry of evoked potentials with images drawn from different locations within a natural scene state-space. We also mapped where the evoked responses to different scenes fall within neural state-space, and assessed how much of the variance defining that space could be explained by particular image statistics. Data were gathered in a steady-state visual evoked potential paradigm whereby participants (n = 18) viewed 700 grayscale visual scenes while undergoing 128-channel EEG. Scene images were contrast modulated at a sinusoidal flicker rate of 5 Hz for 6000 msec while participants engaged in a distractor task at fixation. Electrode data with the highest signal-to-noise ratio were submitted to a principal component (PC) analysis on a participant-by-participant basis. The first three PCs were found to account for a median of 90% of the response variance. Interestingly, the distribution of responses to different scenes within that space is highly non-Gaussian, with the first PC defining that space showing remarkable stability across participants (Cronbach's alpha = 0.93). Further, stimuli in image state-space were mapped to their response location in neural state-space with minimal error using linear transformation matrices. Lastly, a median of 37.7%, 14.6%, and 11.1% of the variance along the first three PCs (respectively) is explained by standard image statistics (amplitude spectrum slope, band-limited contrast, orientation bias, phase-only second spectrum slope, structural sparseness, and whitened skewness and kurtosis), with phase-only second spectrum slope accounting for most of the unique variance. Together, the results demonstrate that this approach has much promise for understanding how the brain maps our visual world onto neural representations.

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43.308 The contrast response function is enhanced according to local subjective importance in natural images
Wietske Zuiderbaan[1](wietske.zuiderbaan@gmail.com), Serge O Dumoulin[1,2,3]; [1]Spinoza Centre for Neuroimaging, Amsterdam, Netherlands, [2]Experimental Psychology, Utrecht University, Utrecht, Netherlands, [3]Experimental and Applied Psychology, VU University, Amsterdam, Netherlands

INTRODUCTION Perception is based on the interaction between sensory information and our knowledge of the world, yet there is no consensus about how this interaction influences the neural signal in early visual areas. According to different inference theories, the knowledge-based perceptual hypothesis can either suppress or boost the sensory information represented in early visual areas. Suppressive or boosting effects are often referred to as predictive and effective coding respectively. Here we investigated the effect that the knowledge-based perceptual hypothesis has on the contrast response function in early visual cortex. METHODS We used 7T MRI to measure responses to viewing of natural images. For each image, we quantified the amount of RMS-contrast (sensory-driven) and subjective importance (knowledge-based). The subjective importance was based on the manual delineation of important regions of the image. We also measured the population receptive field (pRF) properties in early visual areas. We used the pRFs to quantify both the amount of RMS-contrast and the amount of subjective importance in the pRF. Combining this with the responses to natural images, we derived the contrast response function (CRF) for pRF locations with high and low subjective importance. RESULTS Based on the inherent variations of contrast in the natural images, we show that we can derive the CRF. This CRF is comparable to those reported in the literature. Furthermore, we show how the CRF is boosted in visual areas V1-V2-V3 for regions of high subjective importance as compared to low subjective importance. We found a similar boost of the CRF for figure vs ground in V1-V2 but not V3. DISCUSSION Subjective importance alters the CRF in early visual areas. We suggest that this alteration reflects the interaction between sensory information and our knowledge of the world. This interaction argues for effective coding and against most conventional implementations of predictive coding.

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43.309 Coding of navigational distance in the visual scene-selective cortex
Jeongho Park[1](jpark203@jhu.edu), Soojin Park[1,2]; [1]Department of Cognitive Science, Johns Hopkins University, [2]Department of Psychology, Yonsei University

To successfully navigate, it is crucial to accurately detect local boundaries that impose limits to one's locomotion. In this study, we aim to directly examine the neural representation of navigational distance to a boundary in a scene. In Experiment1, we rendered artificial images that contain a transparent glass-wall, which presents a local boundary that limits one's navigation while keeping the visibility of a global boundary. The condition varied in 3 visible distance levels (Near, Middle, Far) and 2 local boundary levels (Glass-Wall, No-Glass-Wall). In Glass-Wall conditions, a transparent glass-wall was added to each environment, and critically, the navigational distance to the glass-wall was kept the same across all visible distance levels. We predicted that if there is a brain region representing the navigational distance, activation of such region will be distinguishable in No-Glass-Wall conditions but not in Glass-Wall conditions. During fMRI scans, participants (N=15) viewed the stimuli in a blocked design. We found a significant interaction between visible distance and local boundary in a scene-selective region, specifically Occipital Place Area (OPA). A step-wise increment of BOLD response was observed as the navigational distance increased in No-Glass-Wall conditions, but not when the navigational distance was kept the same in Glass-Wall conditions. Multivoxel pattern analysis also confirmed consistent results. These results suggest that OPA is sensitive to the changes of navigational distance in visual scenes. In Experiment 2, we tested a condition that contains a boundary that does not block one's navigation: curtains. Behavioral experiment showed that participants evaluate the navigational distance of curtain conditions to be similar to that of No-Glass-Wall conditions, suggesting the importance of functional constraint of a boundary (N=18). Preliminary fMRI results using the SVM classification replicate Experiment 1 findings. These results suggest that human scene-selective cortex acts as a perceptual source of critical information for the navigation.

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43.310 Dynamics of "Gist" Processing
Karla K Evans[1](karla.evans@york.ac.uk), Lucy J Spencer[1], Daniel H Baker[1]; [1]University of York, UK

Gist is a series of characteristics humans extract rapidly to make judgments about the content and nature of a scene. This quick extraction of information happens for multiple image categories at the same time, but these outputs can show either probability summation or destructive interference depending on the task contingencies at hand (Evans et al., 2011). We explored the dynamics of gist processing and modulation of neuronal response due to changing task contingencies across three rapid event-related experiments. We used both univariate cluster-corrected comparison of ERPs and multivariate pattern analysis of electroencephalographic responses across the scalp. In the experiments, observers were asked to categorize briefly presented (25 ms) pre-cued images from different categories. In experiments 1 & 2 we examined conflict arising when both the cued target and task irrelevant but primed target are present. In experiment 3 we expanded the number of categories and introduced additional task contingencies (find either both or either of the two targets). Findings show that the gist of an image is discriminable from 50 ms post stimulus onset. Onset of different patterns of responses to different target categories is modulated by task relevance. When image categories are potential targets the differentiating pattern for diverse categories arises at the same time as target detection (50-100 ms post stimulus). However, non-target image categories are differentiated later, 100 ms after the target gist is detected. Lastly, changes in task contingency influence differentially the pattern of EEG responses, but only from around 300 ms post stimulus onset. In conclusion, we are able to differentiate between gists as soon as we detect the presence of the cued target but this differentiation is delayed when the categories are not task relevant. The effects of task contingencies modulate rapid gist processing, but only at the decisional stage.

43.311 Strategic Deployment of Attention in Online Causal Judgment: A Computational Model
Andrew Lovett[1](andrew.lovett.ctr@nrl.navy.mil), Gordon Briggs[1], Kevin O'Neill[1], Paul Bello[1]; [1]U.S. Naval Research Laboratory

Demonstrations of top-down effects in perception typically concern objects, events, and relations that are present in a scene. However, there is a class of relations that depend on what fails to be present: causal relations. Eye-tracking evidence reported in (Gerstenberg et al., 2017) suggests that subjects strategically deploy attention to non-actual events in service of causal judgment, but not when their task merely requires tracking actual outcomes. We have developed a computational model in the ARCADIA framework (Bridewell & Bello, 2016), that captures the differential patterns of attentional deployment reported in Gerstenberg et al. In Gerstenberg's task, a ball B moves towards a gate G. Meanwhile, a second ball A collides with B, with B subsequently entering (or missing) G. The model is interrogated either on whether B entered G or on A's causal contribution to B's entering G. For the causal judgement, the model initiates a coarse sweep of spatial attention along B's pre-collision trajectory, checking whether it intersects G. If the intersection is judged to be partial, finer-grained sweeps are attempted. For the outcome judgement, such attentional sweeps are not needed. The model generates ratings for each judgement that closely match human ratings, $r(16) = .93$, $r(16) = .92$, both $ps < .001$. Because eye movements in the model follow covert attention shifts, the model generates predictive saccades along B's pre-collision trajectory when it is making a causal judgement. Consistent with human behavior, the number of predictive saccades tracks the fineness of attentional sweeping required to determine whether B will enter G. These saccades correspond to what would have been the case for the B-G relationship prior to collision, and thus can represent non-actual events that inform causal judgment. Future research will explore the attentional strategies and associated eye movements used to verify other causal and spatial relations.

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43.312 Dissociable dynamic network organization states for representations of relative and absolute spatial relations
Xin Hao[1](psyhaoxin@163.com), Zhencai Chen[1], Yiying Song[1], Xiangzhen Kong[1], Jia Liu[2]; [1] State Key Laboratory of Cognitive Neuroscience and Learning, IDG/McGovern Institute for Brain Research, Beijing Normal University, Beijing, China, [2]Beijing Key Laboratory of Applied Experimental Psychology, School of Psychology, Beijing Normal University, Beijing, China

Identifying and extracting spatial relations is a fundamental aspect in spatial navigation. The representations of two main types of spatial relation, relative and absolute spatial relations, have been investigated in numerous studies, gaining some insights into the different brain regions involved. However, no study has investigated the neural basis for representations of relative and absolute spatial relations from a dynamic network view. Here, we used a dynamic functional connectivity (FC) approach to explore how representations of relative and absolute spatial relations are associated with different dynamic FC states of the navigation network in a large cohort of participants (N = 226). After identifying the navigation network, we separated it into a core and an extended network with a modularity analysis. We clustered all time windows during resting-state scanning into two typical states for dynamic FC within the core network (or dWNC), a weak state (Mean FC = 0.31) and a strong state (Mean FC = 0.68). Meanwhile, two typical states for dynamic FC between core and extended network (or dBNC) were identified, a negative state (Mean FC = -0.26) and a positive state (Mean FC = 0.19). Interestingly, we found that topographic scene recognition based on relative spatial relations was only related to properties of the weak state of dWCN, but not to any states of dBNC. In contrast, sense of distance based on absolute spatial relations was associated with properties of the negative state of dBNC, but not with any states of dWCN. These results indicated representation of relative spatial relations was related to integration within the core navigation network, while representation of absolute spatial relations was related to interactions between the core and extended navigation network. In sum, our study reveals double dissociation in dynamic network organization states underlying the representations of relative and absolute spatial relations.

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43.313 Neural representations of reachspaces dissociate from scenes and objects
Emilie L Josephs[1](ejosephs@g.harvard.edu), Talia Konkle[1]; [1]Department of Psychology, Graduate School of Arts and Sciences, Harvard University

The human visual system shows a division of labor between object-processing pathways and scene-processing pathways. However, in continuous visual experience, singleton objects and full-scale scenes represent only the extremes—intermediate scales of space, e.g. the view of a desk-top or a kitchen counter, are also frequently experienced. How do these intermediate "reachspaces" drive visual cortex? On one hand, reachspaces are like scenes in that they have spatial structure and contain multiple objects, and thus may drive neural responses similar to full-scale scenes. However, in visual search behavior, reachspaces perceptually dissociate from full-scale scenes (Josephs & Konkle, VSS 2017), raising the possibility that there may be neural regions tuned to reachspace features. To test this, in Experiment 1, observers (N=10) underwent whole-brain functional neuroimaging while viewing pictures of objects, scenes, and reachspaces in a standard blocked design (N=50 images per view type). A conjunction analysis revealed a bilateral region in posterior lingual gyrus with a stronger response to reachspaces over both singleton objects and full-scale scenes. Further, in all classic scene and object regions, reachspaces dissociated from both objects and scenes with an intermediate response magnitude. In Experiment 2 (N=12), we replicated the existence of the lingual reachspace-preferring region (10/12 subjects), and found some evidence for additional reachspace-preferring regions in inferior parietal sulcus (6/12 subjects) and superior parietal lobule (8/12 subjects). Taken together, these results establish that reachspaces have a distinct representational signature from both scenes and objects. Broadly, they provide initial evidence that intermediate-scale spaces engage a distinct network of regions, in addition to object and scene networks, comprising a new large-scale division of neural responses.

43.314 A Graph-like Neural Representation of Indoor Spaces Revealed Using fMRI
Liwei Sun[1](liwei.sun.gr@dartmouth.edu), Sebastian M. Frank[2], Peter U. Tse[1]; [1]Department of Psychological and Brain Sciences, Dartmouth College, [2]Department of Cognitive, Linguistic, & Psychological Sciences, Brown University

An internal spatial representation of the indoor structure of a familiar building guides us to our destinations within the building. Here, we investigated how interconnectedness between subspaces (rooms) in a building is represented in the brain. We designed a square-shaped space with four corner rooms connected by four equal-length corridors in a virtual reality world. Two of the corridors were partitioned into three subspaces (rooms), while the other two were non-partitioned. Participants were trained to memorize the indoor space while searching for target objects fixed in the corner rooms as landmarks. Participants were fMRI scanned while viewing the target objects before and after the training. Results reveal a significant increase in multivariate classification accuracies of object-room associations in the occipital place area (OPA) after training. Moreover, the objects separated by the partitioned corridor were represented as further away than the objects separated by the non-partitioned corridor in the parahippocampal place area (PPA) after training, measured by neural distance (1 - correlation). This result suggests that the human brain codes the indoor spaces in a manner analogous to a graph-like representation with subspaces (rooms) as nodes.

43.315 Perceiving the average blur in images
Siddhart Srivatsav Rajendran[1](sidopto@gmail.com), Courtney Matera[1], Michael A Webster[1]; [1]University of Nevada, Reno

Perception is dominated by the sharper of two features when the features are superimposed spatially or combined neurally in dichoptic viewing. However in natural viewing blur often varies across the image because of factors such as limited depth of focus. We asked how the average blur is processed in images with spatial variations in blur. Images corresponded to an ensemble of local edges with varying levels of Gaussian blur, or a matrix of textures (pebbles) with subregions blurred or sharpened by varying the slope of the amplitude spectrum. With the local edges, subjects judged the average blur in the image by varying the blur level of a matching stimulus using a 2AFC staircase. Three different ensembles with low, moderate, and high average blur levels were tested. In this task, subjects' estimates of the average blur in ensembles reliably tracked the mean blur level in the array, and did not significantly differ from the mean. With the texture, blur in a test image was adjusted with a staircase to estimate the level at which the image appeared in focus. These judgements were repeated after adapting to different spatial ensembles of blur variations or to an image with the same average level of uniform blur. Four ensembles with sharp, focus, moderate and high average blur were tested. Adaptation aftereffects were similar for uniform or varying blur patterns with the same mean, and like the previous task, reliably tracked the average blur level. Thus, participants can reliably estimate the average blur level in a scene composed of spatially varying blur. Moreover, adaptation to the blur is determined by the average. This suggests that in the perception of blur there is not a bias toward sharper features when the component blur levels are spatially distinct.

Acknowledgement: EY010834

43.316 A Top-Down, Scene Model-Based Perceptual Aftereffect
Allan C. Dobbins[1](adobbins@uab.edu), Jon K. Grossmann[2]; [1]Dept. of Biomedical Engineering, University of Alabama at Birmingham, [2]SoundHound Inc., Santa Clara, CA

A transparent kinetic dot object (KDO) appears to rotate in depth and has ambiguous rotation. A rotational aftereffect can be induced via bottom-up manipulations involving luminance, motion or disparity. Superimposing the KDO on a uniformly translating field of dots induces perception of the front surface of the KDO as rotating opposite to the translating field (Sereno & Sereno, 1999). Either a large disk or an annulus of translating dots is a sufficient inducing stimulus for a rotational aftereffect (Zotov, Grossmann & Dobbins, 2007). Here we explore rotational aftereffects via high-level inducers. A rotating Necker cube has ambiguous tilt and rotation, but the two are coupled. In an array of rotating Necker cubes all appear to have shared tilt rather than shared motion with a profound tilted-down or viewed-from-above bias (Dobbins & Grossmann, 2010). In the first experiment a rotating Necker array with shared tilt/rotation coupling

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is employed. The array's rotation sense is determined by the viewed-from-above constraint. The array is viewed for 20 seconds, followed by an ambiguously rotating KDO for 20 seconds. Observers exhibit a rotational aftereffect in which, upon its appearance, the KDO rotates oppositely to the inducer. Since the cubes are perspectiveless with balanced motion, the rotational aftereffect cannot be a bottom-up effect. In a second experiment, observers viewed a rotating KDO (ellipsoid) that cast a shadow on the floor. The rotating shadow induces the KDO to rotate consistently with the shadow's apparent rotation. When the shadow disappears, the KDO undergoes a rapid switch to the opposite sense of rotation. In control conditions in which the elliptic shadow deforms but is not consistent with rotation, there is neither rotational induction nor aftereffect. Because the shadow is remote from the object, we conclude that the rotational aftereffect is a high-level phenomenon of object-scene interpretation.

43.317 **Separable effects of similarity and contrast on detection in natural backgrounds** Carlos Dorronsoro[1,2](cdorronsoro@io.cfmac.csic.es), Calen Walshe[1], Steve Sebastian[1], Wilson S Geisler[1]; [1]Center for Perceptual Systems, University of Texas at Austin, [2]Instituto de Optica, Consejo Superior de Investigaciones Cientificas (IO, CSIC), Madrid, Spain

Detection of spatial targets is a fundamental visual task. As with laboratory synthetic stimuli, performance in natural backgrounds depends on multiple dimensions. Using a constrained sampling approach (sorting millions of gray-scale natural background patches into narrow bins along multiple dimensions) Sebastian et al. [1] found that the thresholds of template-matching observers are the separable product of the local luminance (L), contrast (C), and phase-invariant similarity (S) of the natural background (similarity was the cosine similarity between the amplitude spectrum of the background and target). They also showed that for each dimension alone, human thresholds are consistent with this prediction from natural scene statistics. Here we tested whether human thresholds are consistent with the prediction of separability for the dimensions of contrast and similarity. Specifically, we parametrically measured threshold for an additive Gabor target (4 cpd) for 3 levels of contrast X 5 levels of similarity. These levels of contrast and similarity spanned the ranges observed in the natural backgrounds, with the restriction that the thresholds could be measured without significant clipping in the display. Thresholds for each bin were estimated from psychometric functions, where the natural backgrounds were randomly sampled from the bin without replacement. The level of luminance in the present experiment was approximately twice that in the Sebastian study, and three subjects from the Sebastian study ran in the current study. Combining the data across the two studies, we found (in agreement with the natural scene statistics) that human thresholds were approximately consistent with separable Weber's law for luminance, contrast and similarity: threshold = k0 x (L+k1) x (C+k2) x (S+k3). Thus, human detection performance appears to be predicted (up to a single scale factor) directly from the natural-image statistics over much of the space of natural background patches. [1] Sebastian, Abrams and Geisler, PNAS, 2017

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43.318 **High-level image structure modulates low-level orientation sensitivity** Christianne JH Jacobs[1](christianne.jacobs@uclouvain.be), Charlotte Raskopf[1], Kirsten Petras[1], Valerie Goffaux[1]; [1]Psychological Sciences Research Institute (IPSY), UC Louvain

Orientation selectivity has been investigated mainly with simple, narrow-band visual stimuli, such as gratings or Gabor patches (e.g. Appelle, 1972) showing a so-called oblique effect, i.e. lower sensitivity for oblique orientations compared to cardinal orientations. However, for broad-band natural scene stimuli the visual system actually shows a reverse pattern of orientation preference with higher sensitivity to oblique than cardinal orientations (i.e. cardinal effect), which has been related to the cardinal dominance in natural image statistics (Hansen and Essock, 2004). In addition to these low-level stimulus properties, orientation sensitivity might be influenced by high-level properties, like the differential diagnosticity of orientation cues. Until now such high-level modulations of orientation sensitivity have barely been considered. Here, we used an orientation detection paradigm to investigate orientation sensitivity across different broadband image categories varying in phase, spectral slope, and the diagnosticity of information across orientations: upright, inverted, and scrambled faces, intact and scrambled scenes. We selected orientation-matched face and scene images and made them isotropic (i.e. all orientations carry equal amplitude). We created an orientation increment by increasing the relative amplitude of a 45°-wide broadband centered on one of four possible orientations: horizontal (0°), 45°, vertical (90°), and 135° (Hansen and Essock, 2004). In each session, isotropic and incremented stimuli of one of five categories were presented to the participants (N =10) who indicated the presence or absence of the orientation increment on each trial. Our results suggest that the cardinal effect generalizes to all tested categories. However, we also find a main effect of stimulus category, with orientation sensitivity being highest for scrambled scenes (and scrambled faces), and lowest for intact scenes. This indicates that even when image properties are matched, the high-level structure of the image modulates low-level orientation sensitivity.

43.319 **Measuring local symmetry in real-world scenes** John D Wilder*[1,2](jdwilder@cs.toronto.edu), Morteza Rezanejad*[3], Kaleem Siddiqi[3], Sven Dickinson[2], Allan Jepson[2], Dirk B Walther[1]; [1]Department of Psychology, University of Toronto, [2]Department of Computer Science, University of Toronto, [3]Centre for Intelligent Machines, McGill University *contributed equally

Symmetry is an important principle for grouping visual information in complex scenes. Last VSS, we (Wilder et al., 2017) showed that symmetry greatly influences human observers' ability to categorize a scene. We designed a method for measuring "ribbon symmetry" in a line drawing and showed that observers categorized scenes much more accurately when presented with half-images containing the most symmetric pixels compared to those containing the least symmetric pixels. Ribbon symmetry focuses mostly on parallelism in a scene. In the real world, parallel lines tend to converge due to linear perspective. To avoid penalization of this tapering of parallel lines, we here present modifications to our previous measure of symmetry in order to test to which type of symmetry the visual system is most sensitive. Our original method looked at how the radius of a maximal inscribed disc changes relative to neighboring maximal discs, and compared this change to a threshold. The number of discs in a local region that exceeded the threshold became the symmetry score. We now use the derivative of the radius function along the symmetric axis between two contours as a continuous method that does not require setting a threshold. While largely matching the results of the original method, this new method allows us to capture tapering contours by considering the second derivative of the radius function as well. Now, 3D parallel lines that are not parallel in 2D, such as those receding to the vanishing point in a highway scene, also receive a strong symmetry score. This broader definition of symmetry captures scene properties relevant for human scene categorization.

43.320 **A causal model of recursive scene parsing in human perception** Ning Tang[1](ningtang@zju.edu.cn), Haokui Xu[1], Jifan Zhou[1], Rende Shui[1], Mowei Shen[1], Tao Gao[2]; [1]Department of Psychology and Behavior Science, Zhejiang University, [2]Departments of Statistics and Communication Studies, UCLA

A visual scene can be recursively parsed into parts and sub-parts. We present a causal model of scene parsing that can synthesize and identify parse trees, predict perceptual complexity, and pass a (limited) Turing test. It describes the causal process of generating a scene as splitting it recursively with vertical and horizontal cuts, modulated by two parameters: (a) Splitting Factor (SF) – a large SF favors splitting a part into more sub-parts, generating a wide and shallow tree; (b) Part Similarity (PS) – a large PS favors evenly splitting a part into sub-parts. Given a scene, it infers the best parsing tree by evaluating the number of parts and their similarities at each partition. It inspires three human experiments beyond RT/accuracy measurements. (1) "Just cut it". Participants freely cut a blank scene into 6 rectangles recursively. With human-generated images, the model removed all free parameters by estimating human SF and PS priors. (2) "Complexity comparison". Some scenes are immediately perceived as more complex than others. Scene complexity can be quantified as "information content", determined by the probability of generating that scene (higher probability carries less information). Participants ranked the complexities of 20 scenes via paired comparisons. The model

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ranked the same images by computing their information contents. The result revealed a strong correlation between human and model rankings ($r2 = 0.85$). (3) Turing test. Each scene can be interpreted by multiple parsing trees. Participants viewed a scene and one parsing tree, then reported whether the tree was generated by a human or machine. Two baseline models were introduced: (a) the causal model with non-informative SF and PS priors; (b) a model uniformly sampling a tree from valid ones. Only the causal model with human priors passed Turing test. These results demonstrate how to formalize human scene parsing with a causal model.

Perceptual Learning: Models and neural mechanisms

Monday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

43.321 **Estimates of category means are biased away from the category boundary following an orientation-categorization task** Chris W Grimmick[1](chrisgrimmick@gmail.com), Elyse H Norton[1], Michael S Landy[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Prior expectations and contextual information influence perception. These expectations can develop rapidly. Even a single decision to categorize a stimulus can bias a subsequent estimate in the direction of the chosen category. To determine the effect of sensory uncertainty on estimation bias, we examined the mean estimates of orientation categories following a sequence of categorization decisions. On each trial, an ellipse was drawn from one of two partially overlapping categories of orientation (category variance was constant across conditions). Observers reported the category of the ellipse and received feedback. After each block ($N = 200$), observers estimated the mean orientation of each category and placed confidence intervals around their estimates. To incentivize accurate placement, points were awarded for capturing the true mean and for small confidence intervals. No immediate feedback was provided for category-mean estimates. Task difficulty was manipulated across three sessions by changing the ellipse aspect ratio. Within a session, the category boundary varied across blocks and the distance between category means was set based on a separate threshold-measurement session to yield constant d'. Observers' estimates of category means were biased away from the category boundary. These repulsive effects were greater at cardinal orientations, where sensory thresholds of orientation discrimination are lowest. The difference in bias across orientations was attenuated at the highest level of task difficulty, where sensory thresholds of orientation discrimination are highest. This pattern was predicted by a parameter-free model that ignores stimuli that cross the category boundary (i.e., stimuli that would be categorized incorrectly) and estimates category variance in JNDs. Human judgments are self-consistent. That is, only stimuli consistent with one's categorization decisions are used for estimation. Furthermore, perception of variance is in units of sensory threshold. Our results suggest a fundamental relationship between one's discrimination threshold and estimation bias.

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43.322 **Modelling network mechanisms for maintaining neural population homeostasis in visual adaptation** Xuexin Wei[1,3,4](weixxpku@gmail.com), Kenneth D Miller[2,3,4]; [1]Department of Statistics, [2]Department of Neuroscience, [3]Center for Theoretical Neuroscience, [4]Columbia University in the City of New York

The visual system constantly adapts to the statistical structure of its inputs. Recent experiments suggest that surprisingly adaptation in V1 can maintain population homeostasis, e.g. roughly equal responses of cells across preferences despite biased stimuli (Benucci et al., Nature Neuroscience, 2013). However, it remains open how the system achieves such sophisticated gain control. To better elucidate the computational mechanisms, we formulated a network model for V1 adaptation. The model neurons receive inputs via both feedforward and recurrent connections. We incorporated multiple neurophysiologically realistic mechanisms for adaptation, including short-term plasticity (e.g., pre-synaptic depression), as well as adaptation currents proportional to the neuron's integrated firing history exponentially weighted at multiple time scales. We simulate the neural responses based on both uniform and biased stimulus ensembles. For the latter, one particular orientation (the adaptor) is over-represented. We systematically vary the strength of pre-synaptic depression and the adaptation current, and find that, for a range of parameter values, the resulting network can well maintain first-order (mean responses) and second-order (correlations) homeostasis, consistent with Benucci et al. Also, the model robustly accounts for the experimentally observed repulsive shift of tuning curves and population activity during adaptation. Furthermore, fitting the model neural responses using a two-gain-factor model (stimulus-specific and neural-specific gain) proposed by Benucci et al., the resulting gain factors are comparable to the experimental report, with the stimulus-specific gain generally dominating. Our model also generates new predictions, including that the amount of response equalization depends on the contrast. In particular, stimuli with lower contrast should lead to less perfect equalization. Our results suggest specific mechanisms that could maintain population homeostasis during a particular set of adaptation experiments. In general, our model may provide a modelling framework for studying other commonly used adaptation protocols in psychophysical and neurophysiological experiments.

43.323 **A Large Scale Video Dataset for Event Recognition** Mathew Monfort[1](mmonfort@mit.edu), Bolei Zhou[1], Sarah Adel Bargal[2], Alex Andonian[1], Kandan Ramakrishnan[1], Carl Vondrick[1], Aude Oliva[1]; [1]CSAIL, MIT, [2]Computer Science, Boston University

"The best things in life are not things, they are moments" of raining, walking, splashing, resting, laughing, crying, jumping, etc. Moments happening in the world can unfold at time scales from a second to minutes, occur in different places, and involve people, animals, objects, and natural phenomena, like rain, wind, or just silence. Of particular interest are moments of a few seconds: they represent an ecosystem of changes in our surroundings that convey enough temporal information to interpret the auditory and visually dynamic world. We present the Moments in Time Dataset, a large-scale human-annotated collection of one million videos corresponding to dynamic events unfolding within 3 seconds. These short temporal events correspond to the average duration of human working memory (a short-term memory-in-action buffer specialized in representing temporally dynamic information). Importantly, 3 seconds is a temporal envelope which holds meaningful actions between people, objects and phenomena (e.g. wind blowing, objects falling on the floor, picking something up) or between actors (e.g. greeting someone, shaking hands, playing with a pet, etc). There is a common transformation that occurs in space and time involving agents and/or objects that allows humans to associate it with the semantic meaning of an action despite a large amount of visual and auditory variance in the events belonging to that action. The challenge is to develop models that recognize these transformations in a way that will allow them to discriminate between different actions, yet generalize to other agents and settings within the same action. This dataset, designed to have a large coverage and diversity of events in both visual and auditory modalities, can serve as a new challenge to develop models that scale to the level of complexity and abstract reasoning that a human processes on a daily basis.

43.324 **Task Difficulty Mediates the Effects of Roving on Performance** Gizay Ceylan[1](gizayceylan@gmail.com), Aaron M Clarke[1]; [1]1. Bilkent University, Neuroscience Department, Ankara, Turkey

Prior research has shown perceptual learning to be possible in the absence of feedback, but to progress more quickly with feedback (Herzog & Fahle, 1997). These two findings implicate both unsupervised and supervised mechanisms in perceptual learning. Recent work by Frémaux, Sprekeler, and Gerstner (2010) has shown that mixing these two learning mechanisms may potentially lead to synaptic drift and disruption of learning when simultaneously learning two tasks with differing difficulty levels. When the two tasks are equated for difficulty, however, the model predicts no disruption of learning. These modeling results could potentially explain why perceptual learning for two randomly intermingled tasks (termed "roving") has sometimes been found to disrupt learning (Parkosadze, Otto, Malania, Kezeli, & Herzog, 2008; Tartaglia, Aberg, & Herzog, 2009), but not always (Tartaglia et al., 2009). Furthermore, roving has been shown not only to disrupt learning, but also to disrupt task performance for a learned task (Clarke, Grzeczkowski, Mast, Gauthier, & Herzog, 2013). Here we tested the effects of matched or mixed task difficulty levels on performance for a learned task under roving conditions.

Participants performed a bisection task where they viewed three vertical lines and had to indicate whether the central line was closer to the left or right of the interval defined by the three lines. Performance improved with training. Following training, we roved the trained bisection stimulus with a narrower bisection stimulus. Crucially, we split subjects into two groups – one where the roved stimuli were equated for difficulty using an adaptive staircase method, and one where the stimuli were made to differ in difficulty levels by using different staircase procedures for each. We found that indeed, roving's effects depend on task difficulty level in the predicted way. Furthermore, training participants over multiple days revealed that roving's deleterious effects decrease with increasing learning.

43.326 **Perceptual learning trial-by- trial in a task-roving paradigm** Jiajuan Liu[1](jiajuanl@gmail.com), Barbara Dosher[1], Zhong-Lin Lu[2]; [1]Department of Cognitive Sciences, University of California, Irvine, [2]Department of Psychology, The Ohio State University

In many circumstances, perceptual learning is tracked at a fairly coarse grain of measurement, often in blocks involving a hundred trials or more. Embedded in this paradigm is an implicit assumption that learning can be fully measured in the performance improvement across blocks. However, in most models of perceptual learning, learning potentially occurs after each trial. Such modeling calls for a re-examination of the trial-by- trial learning dynamics in perceptual learning experiments. In this study, we examine the data from a study that compared different forms of intermixed task training - "roving" of stimuli. Observers make orientation judgments (clockwise or counterclockwise) about sets of base angles drawn from {+/-12deg about -67.5deg, -22.5deg, +22.5deg, and +67.5deg relative to vertical}. Observers judge CW or CCW to 4, 2-similar, 2-dissimilar, or 1 base angles each trained in one of four locations, with an adaptive staircase tracking 75% correct. While the coarse block-wise analysis shows differences among groups in the first session, the trial-by- trial analysis shows the statistical equivalence of the groups at the beginning of training, followed by separation of the more difficult all-4 and 2-similar groups from the 2-dissimilar and 1 base angle group relatively early in the first session, followed by relative improvement of the 2-similar group. Combined with simulations of the specific staircase procedure used, the trial-by-trial analysis also reveals interesting micro-patterns such as within session learning and increasing lapse rate toward the end of a session. A simulation of the integrated reweighting theory (IRT, Dosher et al., 2013) using the same staircase procedure shows very similar micro-structure of contrast thresholds, as well as initial within-session settling of percent correct within the 90% confidence intervals of 75%. This analysis provides important information about the early phase of perceptual learning that is critical to distinguish different learning processes.

Acknowledgement: NEI

43.327 **Perturbation Tolerance of Deep Neural Networks and Humans in Material Recognition** Xing Liu[1](ryu@vision.is.tohoku.ac.jp), Masataka Sawayama[2], Ryusuke Hayashi[3], Mete Ozay[1], Takayuki Okatani[1], Shin'ya Nishida[2]; [1]Graduate School of Information Sciences, Tohoku University, Japan, [2]NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation, Japan, [3]Systems Neuroscience Group, AIST, Japan

We can visually recognize a variety of materials, such as fabric, glass, and metal. A promising approach to elucidate complex visual mechanisms underlying material perception is to construct and analyze artificial neural networks which recognize materials as humans do. We previously (Liu et al., VSS2016) showed that a convolutional neural network (CNN) could recognize material categories of Flickr Material Database (FMD; Sharan et al., 2013) as accurately as humans. The network was developed from a CNN model for object recognition (Simonyan & Zisserman, 2015), and fine-tuned for material recognition with FMD. To compare the performance of humans and CNNs in a broader context, the present study investigated the perturbation tolerance. Specifically, we distorted the material images of FMD by adding Gaussian noise with several levels of standard deviation, and let human participants and a CNN classify images into ten material categories. The CNN was fine-tuned for material categorization, but only with noiseless FMD images (Liu et al., VSS2016). Results showed that the categorization accuracy dropped with the noise level more steeply for the CNN than for humans, implying lower perturbation tolerance for the CNN than for humans. Furthermore, we examined whether the noise tolerance of the CNN could be improved by adding a de-noising network to the original material-recognition CNN in a cascaded manner. We obtained a major improvement to the level of human performance when using a type of de-noising network that learned to match features represented by the following CNN between the original and noisy images of FMD (Johnson et al., 2016), while we obtained only a minor improvement when using another type of de-noising network without CNN feature matching mechanisms (Isola et al., 2016). Although behavioral similarity does not imply computational similarity, these findings provide novel insights into human visual mechanism for material recognition.

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43.328 **Effect of perceptual training on neural correlates of radial-tangential anisotropy in visual crowding** Mark Greenlee[1](mark.greenlee@psychologie.uni-regensburg.de), Maka Malania[1], Maja Traurig[1], Tina Plank[1]; [1]Institute for Experimental Psychology, University of Regensburg

One of the characteristic features of visual crowding is radial-tangential anisotropy, i.e. the crowding area has an ellipsoid shape that is elongated along the radial axis connecting target with the fovea. Kwon et al (2014) explored the neural correlates of this anisotropy in early visual cortex. They found a reduction of BOLD signal in V1 while the target was presented together with radially arranged flankers compared to the condition when only radial flankers were presented. The opposite finding holds for tangentially arranged flankers. There is further evidence (Chung et al., 2010) that the spatial extent of crowding can be altered by training. Here we asked whether such an alteration of the crowding area would be reflected in the BOLD responses in early visual cortex after training on a crowding task. Six healthy volunteers participated (mean age 23.5 years). A Landolt-C optoype was used as a target surrounded by same-sized circles as flankers (0.75°, target-to-flankers spacing = 0.94°) presented at 6.5° eccentricity in the upper-right visual quadrant. High-resolution T1-weighted anatomical images and T2*-weighted functional images were obtained by 3-Tesla MRI scanner (Prisma, Siemens). Three of the participants were trained over three consecutive days (total number of trials = 2568) on the same gap-detection task. Post-training fMRI images were then acquired. Prior to training, all participants showed the radial-tangential anisotropy in BOLD signal in early visual areas, i.e. a strong reduction in BOLD signal in the condition with target plus radial flankers, thereby replicating the results of Kwon et al (2014). After training the BOLD signal increased in the target-plus-radial-flanker condition. Our results suggest that changes in BOLD responses after training reflect training-induced plasticity in early visual cortex.

Acknowledgement: DFG

43.329 **Global network reorganization induced by short-term visual association learning** Mengxia Yu[1](yumengxia12@126.com), Yiying Song[2], Jia Liu[1]; [1]School of Psychology, Beijing Normal University, [2]State Key Laboratory of Cognitive Neuroscience and Learning and IDG/McGovern Institute for Brain Research, Beijing Normal University

It has been proposed that visual learning is reflected not only by a change of neural activity in visual cortex, but also by a global reorganization of distributed brain networks involving both high- and low-level regions. Here, we used connectivity pattern similarity approach to assess global network reorganization across the whole brain induced by short-term visual association learning. Subjects were trained to associate a set of artificial line-drawing objects with English letters. After 3 days of association training, subjects went through functional magnetic resonance imaging scanning in which they performed a one-back task on trained stimuli, untrained stimuli, English words, and Chinese characters. We calculated pairwise functional connectivity (FC) between 189 nodes belonging to ten networks across the brain for each condition. We found that training modulated global FC pattern when viewing the trained objects, rendering it more similar to the FC pattern when viewing English words compared with untrained objects. Notably, the FC between low-level visual and sensory networks and high-level attention and cognitive control networks showed higher similarity between English words and trained stimuli

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than untrained stimuli, implicating interaction between bottom-up and top-down processes during learning. Furthermore, the global FC pattern when viewing the trained objects also became more similar to that when viewing Chinese characters after learning, suggesting a language-general effect. In sum, our study revealed global brain network reorganization induced by short-term visual learning and suggested interaction between low-level and high-level networks during learning.

43.330 **Feature-based plasticity revealed by decoded fMRI neural feedback (DecNef)** Zhiyan Wang[1](zhiyan_wang@brown.edu), Masako Tamaki[1], Kazuhisa Shibata[3], Michael S. Worden[2], Yuka Sasaki[1], Takeo Watanabe[1]; [1]Brown University, Department of Cognitive, Linguistic and Psychological Sciences, [2]Brown University, Department of Neuroscience, [3]Nagoya University, Graduate School of Informatics, Department of Psychology

We have proposed the two-stage model in which visual perceptual learning (VPL) consists of feature-based plasticity resulting from passive exposure to a primitive feature in early visual areas and task-based plasticity resulting from task improvements involving higher-stage areas (Watanabe & Sasaki, 2014, Ann Rev Psych). Here we show evidence for feature-based plasticity: VPL of primitive features results from purely passive “exposure” to a motion display consisting of both primitive and complex features. We conducted an experiment consisting of the pre-test, decoder construction stage, DecNef training and post-test. In the decoder construction stage, we used a Sekuler motion display where we perceive local primitive motion directions and the global motion direction that is the spatio-temporal average of the local motion directions. We constructed a decoder that discriminated fMRI signals evoked by two Sekuler displays with different global motion directions. One of the two displays was chosen as a target in a double-blind manner. During DecNef training, activity patterns corresponding to the target display were repeatedly induced in V1/V2 without participants’ awareness of what was being induced (see supplementary info for detailed methods). If the repetitive activations only induce VPL of the local motion directions range, this will be in accord with the hypothesis that feature-based plasticity occurs based on primitive features in a purely passive manner. If these activations induce both VPL of the local motion directions range and VPL of the global motion direction, this will be at odds with the above hypothesis. The training was conducted for 1.5 hrs a day over 3 days. In pre- and post-tests, detection tests were conducted with 16 motion directions. We found that motion detectability was improved only within the local motion directions range with no particular improvement on the global motion direction. That is, we could selectively induce feature-based plasticity.

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43.331 **Finding the baby in the bath water – evidence for training-specific changes in MRI measures of brain structure and function** Cibu P Thomas[1](cibu.thomas@nih.gov), Adam Steel[1], Aaron Trefler[1], Elizabeth Aguila[1], Gang Chen[1], Carlo Pierpaoli[2], Chris Baker[1]; [1]National Institute of Mental Health, [2]National Institute of Biomedical Imaging and Bioengineering

Previous studies have reported training-related changes in MRI-measures of brain structure and function. However, MRI measures can be influenced by factors such as time-of-day (TOD), which may be confounded with pre- and post-training effects. Further, there is limited evidence that any changes are task-specific. Here, in a group of 19 healthy adults scanned over multiple visits, we compared task-specific changes in MRI measures after training in visual and motor tasks, while controlling for TOD. Each visit included scan sessions in the AM and PM. On Visits 1 and 4, participants received no training allowing us to model diurnal changes in MRI measures. On Visits 2 and 3, between the AM and PM scans, participants trained for 90 minutes on a visuo-spatial task (i.e. learning the spatial layout of a racetrack) and left-lateralized motor sequence learning respectively. Multimodal MRI data (Resting state fMRI, T1weighted MRI, Diffusion MRI) were acquired during each scan session. Participants showed significant improvement in behavioral performance in both tasks, after training. Analysis of MRI measures of brain function (e.g. resting state functional connectivity (rsFC)) and structure (e.g. cortical thickness, fractional anisotropy) revealed significant fluctuations in MRI measures of function and structure that were related to physiological changes due to TOD, rather than training. After controlling for the effect of TOD, we found changes in rsFC specific to visuo-spatial learning and motor-sequence learning, although evidence for such specificity was not robust in the structural MRI measures. In addition, we found significant correlations between improvements in behavioral performance and changes in the rsFC, as well as structural measures, but the spatial topography of these regions were different from regions that evinced task-specific changes. In summary, our findings suggest task-specific, training-related changes can be measured using MRI, but highlight the importance of controlling for potential confounds.

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43.332 **Early visual cortex underlies modulation of reactivated perceptual learning** Dean Shmuel[1](dshmuel110@gmail.com), Haggai Sharon[2,3], Nitzan Censor[1,4]; [1]School of Psychological Sciences, Tel-Aviv University, [2]Center for Brain Functions and Institute of Pain Medicine, Tel Aviv Sourasky Medical Center, [3]Sackler Faculty of Medicine, Tel Aviv University, [4]Sagol School of Neuroscience, Tel-Aviv University

Human visual perception thresholds can improve through perceptual learning processes. We utilized the memory reactivation-reconsolidation framework, stemming from studies at the synaptic level, according to which consolidated memories become susceptible to modulations upon their reactivation. Accordingly, brief reactivation of an existing memory opens a limited time-window during which the memory can be updated, degraded or strengthened. We have recently shown that brief reactivations of encoded visual memories are sufficient to improve perceptual discrimination thresholds (Amar-Halpert et al., 2017). Here, we used non-invasive brain stimulation to reveal the neural mechanisms underlying modulation of reactivated visual perceptual learning. We tested whether inhibitory noninvasive repetitive transcranial magnetic stimulation (rTMS) over early visual cortex, following brief reactivation of consolidated visual memory, modulates perceptual learning. Subjects first encoded and consolidated the visual memory by performing four daily practice sessions of the texture discrimination task (Karni and Sagi, 1991). Observers decided whether an array of 3 diagonal bars embedded in an array of horizontal bars was horizontal or vertical. The stimulus was backward-masked, and target-to-mask asynchrony (SOA) was randomly changed within the session to obtain a psychometric curve, from which the SOA discrimination threshold was derived. In the fifth session, the memory was briefly reactivated, followed by inhibitory 1Hz rTMS stimulation over early visual cortex, which was individually localized using functional MRI. Post-stimulation perceptual thresholds were measured on the sixth session. The results show deterioration in subjects’ acquired perceptual thresholds, following inhibitory rTMS to early visual cortex synchronized with memory reactivation. These results indicate that even previously consolidated human perceptual memories are susceptible to modulation following their brief reactivation, involving early visual cortical processing. In addition, the opportunity to non-invasively neuromodulate human perceptual learning utilizing the memory reactivation framework, may have important clinical implications.

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43.333 **Indirect measures of visual cortex plasticity and GABA concentration are not correlated in adults with normal vision** Dania Abuleil[1](dania.abuleil@uwaterloo.ca), Daphne L McCulloch[1], Benjamin Thompson[1]; [1]Optometry and Vision Science, University of Waterloo

Introduction Increases in visually-evoked potential (VEP) amplitude can be induced by rapid visual stimulation. This effect involves LTP mechanisms and provides an acute, objective measure of human visual cortex plasticity. Gamma-aminobutyric acid (GABA) may influence adult visual cortex plasticity. GABA concentration is inversely associated with alternation rate (AR) during binocular rivalry. Therefore, AR provides an indirect measure of GABA levels. Our aim was to test for an association between LTP and AR in young (18-40 years, n = 29) and older adults (60-80 years, n = 18). Two age groups were tested because GABA concentration changes across the lifespan. Methods Binocular rivalry was induced using orthogonal gratings viewed through anaglyphic glasses and ARs were averaged across 6 trials. LTP was assessed by comparing VEP amplitude for an onset/offset checkerboard stimulus (0.3 degree

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checksize, 4 degrees of visual angle) before and after 2 minutes of viewing the checkerboard presented at 9Hz. Pre and post VEPs were recorded for 3 minutes at a baseline frequency of 1Hz. Results ARs were significantly slower in older adults than young adults ($t48=6.043$, $p< 0.001$). LTP induction differed significantly between groups ($F1=20.772$, $p< 0.001$). VEP depotentiation (LTD) occurred in the young adult group ($t28=3.444$, $p=0.002$) vs. potentiation (LTP) for the older adult group ($t17=-2.927$, $p=0.009$). No correlation between AR and the change in VEP amplitude was observed for either group ($p>0.05$). Conclusion AR was not associated with VEP amplitude change following LTP induction. However, we did observe two unexpected effects. 1) Contrary to previous reports, visual cortex LTP could not be induced in younger adults, 2) greater LTP (higher visual cortex plasticity) occurred in the older group that had slower AR (higher visual cortex GABA concentration). Therefore, age substantially alters the response of the visual system to rivalrous stimuli and rapid visual stimulation.

43.334 **Changing object representations during visual production training** Jeffrey D Wammes[1](j.wammes@yale.edu), Judith Fan[2,3,4], Rachel Lee[4], Jordan Gunn[4], Daniel Yamins[2], Kenneth Norman[3,4], Nicholas Turk-Browne[1]; [1]Psychology, Yale University, [2]Psychology, Stanford University, [3]Psychology, Princeton University, [4]Neuroscience Institute, Princeton University

Drawing is a powerful tool for encoding object structure. In prior work, we found that training people to repeatedly draw certain objects reduces feature overlap in their drawings and leads to improved categorical perception for these objects. Here, we used fMRI to test the hypothesis that such effects reflect competitive dynamics during visual production. Specifically, competition may lead to differentiation in the neural object representations, particularly in medial temporal lobe (MTL) regions that encode object memories. Participants were scanned during three experimental phases: pre-training, drawing training, and post-training. During the drawing training phase, participants alternated between drawing two related objects (e.g., table, bed) on an MRI-compatible tablet. During pre- and post-training phases, they repeatedly viewed these, and two other control objects (e.g., chair, bench). We predicted that repeated drawing of the two trained objects would elicit concurrent activation of their representations in MTL subregions, reflecting competition. We further predicted that this competition would result in subsequent differentiation of the trained object representations. To evaluate these predictions, we first fit a GLM to the pre-training phase to generate neural template representations for each object, containing the distributed pattern of parameter estimates over voxels within ROIs. We then fit an analogous GLM to the drawing phase, estimating activity at every timepoint in each drawing trial in each of the four training runs. Based on these run-specific timecourses, we measured the relative expression of the neural template representations of the trained objects, using pattern similarity. Our preliminary results are consistent with a link between competition during training and differentiation: the extent to which both trained objects are co-activated during drawing is associated with differentiation in MTL but not lower-level visual subregions. Together, this work provides new insight into the neural mechanisms by which visual production training can refine object representations.

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43.335 **Later visual areas can adapt to adapted input from earlier visual areas.** Xinyu Liu[1](xinyul@uchicago.edu), Juraj Mesik[1], Stephen A Engel[1]; [1]Department of Psychology, University of Minnesota

Exposure to simple patterns changes neural responses in early visual cortex, an effect known as contrast adaptation. However, when these changed signals propagate to later visual areas they may produce inaccurate responses there, as illustrated by illusions like the tilt aftereffect. Later regions are themselves capable of adapting, however, as in face adaptation. Here we tested whether such higher-level adaptation can normalize, and possibly correct, response to adapted input from earlier areas. Specifically, we tested whether distortions in faces produced by contrast adaptation can be affected by higher-level adaptation, causing the distorted faces to appear more normal. Subjects adapted for 2 min to contrast-reversing checkerboard patches presented near fixation; this contrast adaptation displaced the eyes of a normal face presented at fixation, causing them to appear shifted outward. Subjects viewed 300 msec presentations of these distorted faces in alternation with 6 sec of top-up checkerboard adaptation. Every six repetitions of this face-top-up cycle, subjects judged a test face image presented above fixation. Pilot data showed that the checkerboard adaptation did not transfer to this location, confirming its origin in early visual cortex. Participants judged whether the test face’s eyes appeared to be closer together or further apart than “normal”. Interocular distance of the test face was controlled by a staircase procedure to estimate the distance that appeared normal. Our results showed that after adaptation, subjects’ ($n=7$) estimates of normal eye position in the test face were shifted significantly ($t(6)=-2.23$, $p< 0.05$), in the direction of the distortion produced by the contrast adaptation (outward). Thus, high-level adaptation caused the distorted faces to appear more normal. This pattern suggests that adaptation in early visual areas can propagate up the visual stream and generate adaptation in later regions. Such “meta-adaptation” could possibly correct for coding errors generated by adaptation in early visual areas.

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43.336 **Long-term contrast deprivation increases neural gain in early visual cortex** Stephen A Engel[1](engel@umn.edu), Juraj Mesik[1], Mark Vergeer[1]; [1]Department of Psychology, University of Minnesota

Prolonged exposure to a visual feature, such as a particular orientation or color, generally causes the visual system to adjust its sensitivity to the adapted feature. Such effects of visual adaptation have predominantly been investigated on short timescales of seconds to minutes. Recently, we reported perceptual effects of long-term adaptation, on a timescale of hours to days, using a deprivation paradigm. However, the neural bases of such effects remain unknown. Here we measured neural effects of long-term adaptation using steady-state visually evoked potentials (SSVEPs). Participants adapted to a visual environment that contained little to no vertical energy for a period of 4 hours. They wore a head-mounted display (HMD) with a video camera mounted on top. The video stream was filtered in real-time to remove vertical energy, and the filtered images were presented on the HMD. During EEG recordings, subjects viewed a test plaid comprised of a horizontal and a vertical grating, each contrast reversing at a different temporal frequency. In 90 test trials, 6 sec adaptation “top-up”, using pre-recorded filtered natural video, was followed by a 2.5 sec test plaid presentation. Six dry electrodes integrated into the HMD recorded occipital SSVEPs. The FFT of the signal during each plaid presentation was computed, and the amplitude of the FFT at the two stimulus frequencies quantified the response to each component grating. Recordings were made after 3 minutes of adaptation and after 240 additional minutes in the visually deprived world. The average response amplitude for the vertical component increased after long-term adaptation, while no reliable change in response amplitude for the unadapted horizontal component was observed. These results indicate that long-term contrast deprivation increased neural response selectively for the deprived orientation. The gain changes likely arise in early visual cortex, which is the dominant source of SSVEP response to gratings.

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43.337 **Transcranial random noise stimulation over early visual cortex improves processing of noisy visual stimuli** Michael D Melnick[1,6](mmelnick@mail.cvs.rochester.edu), Woon Ju Park[1,6], Sholei Croom[2], Shuyi Chen[1], Ania C Busza[3], Lorella Batelli[4], Krystel R Huxlin[5,6], Duje Tadin[1,6]; [1]Brain & Cognitive Sciences, University of Rochester, [2]Department of Cognitive, Linguistic & Psychological Sciences, Brown University, [3]Department of Neurology, University of Rochester Medical Center, [4]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of Neurology, Harvard University, [5]Flaum Eye Institute, University of Rochester, [6]Center for Visual Science, University of Rochester

Transcranial random noise stimulation (tRNS) is a form of non-invasive electrical brain stimulation, which has shown promise at improving perceptual processing and learning. Here, we sought to gain insights into the brain mechanism underlying these benefits by using an equivalent noise paradigm along with the Perceptual Template Model (PTM). Subjects performed a two-alternative, forced choice, orientation discrimination of a centrally-presented Gabor patch (1° radius, 1 cycle/°, ±12°

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tilt). Random white noise was added to each Gabor at one of 8, evenly log-spaced increments of luminance contrast, while contrast thresholds were measured using a custom parameterized adaptive staircase that measured the entire threshold-versus-noise curve. Nine subjects completed 3 days of psychophysical testing that included an initial test day to allow subjects practice on the task and two subsequent days where tRNS and sham stimulation were counterbalanced. On stimulation days, four sets of psychophysical measurements were taken: before stimulation, during stimulation, and both 20 and 60 min post-stimulation. Stimulation was high frequency RNS (20 minutes, 2mA, bilateral occipital stimulation over O1 and O2 EEG locations). Compared to same-day baselines and sham stimulation, subjects showed benefits during stimulation that was specific to higher noise levels—an improvement linked by the PTM to improved external noise filtering. This was further confirmed by a grouped hierarchical Bayesian model, in which group hyper-priors for the PTM were compared for stimulation and sham groups. Of the three hyper-priors, only values for the coefficient representing the ability to filter external noise were non-overlapping at 95% highest posterior density (Sham = 2.358, 95% HPD = 2.292-2.388, Stim = 2.682, 95% HPD = 2.587-4.525). These results help account for both positive and negative outcomes of online stimulation, suggesting that tRNS may help boost signals among higher noise stimuli while offering little behavioral benefit at low noise and low contrast.

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43.338 **Changes in Extrastriate Cortical Thickness Caused by Macular Degeneration** Matthew K Defenderfer[1](mdefende@uab.edu), Leland L Fleming[1], Kristina M Visscher[1]; [1]Department of Neurobiology, University of Alabama at Birmingham

Macular degeneration causes loss of central vision while leaving peripheral vision relatively spared. This loss of central vision affects a person's daily life, impairing the ability to perform many tasks associated with central vision such as fine detail discrimination and reading. Some people with macular degeneration, especially those with age-related macular degeneration, may experience decreased engagement in tasks of daily living due to vision impairment, and therefore may make generally less use of cortical areas associated with higher level vision. Loss of central vision has been shown to influence cortical thickness in primary visual cortex (Burge et al. 2016), so that areas representing parts of peripheral vision that are used more after macular degeneration onset are thicker and areas representing central vision that is lost after macular degeneration onset are thinner compared to age-matched controls. How does macular degeneration influence cortical thickness in brain areas associated with higher order vision. In this experiment, we focused on area MT/V5, which is associated with processing moving objects, fusiform face area, associated with processing faces, and brain regions within the frontoparietal and cingulo-opercular networks, associated with cognitive control of vision (Yeo, et al., 2011). Cortical thickness in these regions was examined in a database of 24 people with age-related macular degeneration (AMD) and 23 matched healthy vision controls. AMD participants had significantly thinner cortex in MT, consistent with decreased use of vision for detecting motion in those participants. No significant effects were observed in the other regions we examined. These data provide evidence that some higher-level visual processing regions are atrophied following the loss of central vision.

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43.339 **Using fMRI to Identify Neuronal Mechanisms of Motion Detection Underlying Blindsight** Michèle W MacLean[1,2,3](michele.maclean@umontreal.ca), Vanessa Hadid[1,4], Latifa Lazzouni[1,3], Franco Lepore[1,3]; [1]Centre de recherche en neuropsychologie et cognition (CERNEC), Université de Montréal, [2]School of Optometry, Université de Montréal, [3]Department of Psychology, Université de Montréal, [4]Department of Biomedical Sciences, Université de Montréal

Research on the visually impaired offers a valuable model of functional brain plasticity by showing how sensory inputs reshape cortical activations. Following a unilateral post-chiasmatic lesion affecting the visual cortex, patients suffer a controlateral visual loss referred to as Homonymous Hemianopia. Nevertheless, these patients preserve the ability to unconsciously detect, localize and discriminate visual stimuli presented in their impaired visual field. To investigate this paradox, known as blindsight, we have conducted a study using brain imaging techniques to evaluate the structural and functional impact of such lesion in Homonymous Hemianopia patients. In doing so, we collected whole brain and sliced thalamic fMRI scan sequences during resting state and a motion detection task. Subjects with a right or left hemianopia underwent a series of visual tasks to correlate blindsight performances with neural activity. Accurate performance demonstrates their ability to unconsciously perceive motion presented in the blind hemifield and the presence of residual vision. When compared to neurotypical matched controls, we observed strong anatomical and functional differences as well as asymmetrical BOLD activations. As the main visual pathways were lesioned, these findings suggest that (1) sub-cortical pathways, including the superior colliculus projections to the middle temporal area as well as the new formed pathways absent in normal vision, are responsible for processing and relaying visual information; (2) white matter tracts of the still functioning areas increase in volume; (3) functional connectivity as a whole is modified as there is a bilateral activation of the middle temporal area as opposed to a controlateral activation in normal vision. This reorganization in the structure and function of the visual pathways correlates with behavioural changes, thus offering a plausible explanation for the blindsight phenomenon.

43.340 **Cortical reorganization but no recovery of visual function following an optic nerve injury in mice** Jacqueline L Higgins[1](jl.higgins@umontreal.ca), Marianne Groleau[1], Jérôme Anton[1], Mojtaba Nazari[2], Matthieu Vanni[3], Majid H Mohajerani[2], Elvire Vaucher[1]; [1]Laboratoire de neurobiologie de la cognition visuelle, École d'optométrie, Université de Montréal, [2]Department of Neuroscience, University of Lethbridge, Canadian Centre for Behavioural Neuroscience, [3]Department of Psychiatry, University of British Columbia, Brain Research Centre and Djavad Mowafaghian Centre for Brain Health

Visual deficits by ocular disease or visual system trauma cause lasting damage. To better understand the involvement of cortical plasticity in vision restoration, we aim to evaluate the cortical and visual networks following a deficit over time. A partial optic nerve crush (pONC) serves as an induced visual deficit, allowing for residual vision from surviving cells and cortical plasticity. Thy1-GCaMP6s mice underwent in vivo calcium imaging prior to a bilateral pONC, then 1, 3, 5, 7, 14, 23, and 30 days after. Neuronal responses to monocular light flashes were measured in various cortical visual areas, and correlations between responses were performed. Independently, visual acuity was measured in mice using the optokinetic reflex test in response to moving gratings prior to a bilateral pONC, then 1, 3, 7, 14, 21, and 28 days after. Surviving retinal cells were counted. Following the pONC, the cortical response to the stimulus decreased in V1 and secondary visual areas. Some activity was regained at 3-5 days following the pONC. A loss of correlation between cortical visual areas was also observed, but a recorrelation began around day 5. However, this reorganization was not associated with proportional restoration of visual acuity. There was a drop in the number of surviving ganglion cells following the pONC. Using a lighter pONC intensity showed a partial recovery between days 3-7, and a greater cell survival compared to a strong pONC. There is evidence of cortical reorganization between visual areas following the pONC, indicating that plasticity can occur at the cortical level. The optokinetic reflex test showed a significant visual loss following the pONC, but no recovery. However, a behavioural recovery could be obtained with a lighter crush, suggesting that residual cells may be needed for recovery. This indicates that visual loss and plasticity can be observed behaviourally.

Acknowledgement: Vision Health Research Network

Development: Lifespan and models

Monday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

43.341 **Computational Study of Changes to Cortical Vision with Age** Sarah Cavanagh[1](scavanagh4@fordham.edu), Daniel D Leeds[1,2]; [1]Department of Integrative Neuroscience, Fordham University, [2]Department of Computer and Information Sciences, Fordham University

Computational models of cortical visual perception have become a major area of focus in recent years. Convolutional neural networks currently dominate the field, reporting significant abilities to account for cortical representations from V1 to inferotemporal cortex (e.g., Yamins 2014). However, Medial Axis/Shock Graph representations is a more compact visual model that shows promise explaining activity in targeted cortical regions (e.g., Leeds 2013 and Lescroart 2013). The varying matching strengths between visual model representations and cortical region representations suggest diverse cognitive strategies employed across the brain, and across subjects. Correlates of age and cognitive acumen with strategies for visual representation have been explored to some extent, but are generally limited to age-related changes to the size of cortical receptive fields (Brewer 2014, Chang 2015), rather than broader shifts in encoding strategies. In the present study, we explore the effects of age on shifting representations employed in cortical vision. We adapt behavioral data and fMRI neuroimaging data from Stern (2014) to model cortical responses to 111 line patterns from six subjects aged 20 through 80. Subjects performed a pattern comparison task in the scanner. We divide line stimuli into seven classes of increasing shape complexity, computed by the Shock Graph vision model (Kimia 1995). Voxel activity was correlated with the onset of stimuli from each class separately. A division in voxel-level preferred stimulus groups was observed in the early and mid-level ventral visual pathway, favoring more complex shapes at earlier stages. Locations of "simple" versus "complex" class-selective voxels in visual cortex varied with unclear connection to age. However, simple shapes appeared to more strongly correlate to activity in older subjects and complex shapes appeared to more strongly correlate to activity in younger subjects. Shock-graph representations indicate shape-based cortical selectivities in early and mid-level vision, with potential variations influenced by age.

43.342 **Pinwheel-like Iso-Orientation Domains in a Convolutional Neural Network Model** Eshed Margalit[1](eshed.margalit@gmail.com), Hyodong Lee[2], James J DiCarlo[2], Daniel LK Yamins[1]; [1]Department of Psychology, Stanford University, [2]Department of Brain and Cognitive Sciences, MIT

Introduction A hallmark of the mammalian visual system is the orderly arrangement of neurons into functional maps, ranging from pinwheel-like representations of oriented stimuli in early visual areas (Bonhoeffer and Grinvald, 1991) to category-selective regions (e.g., face patches) in higher visual areas (Kanwisher et al., 1997). Despite the identification of such maps in many species, it remains unclear which characteristics may depend on visual experience and, critically, which kinds of visual experience are necessary and sufficient for the formation of such maps. Methods Here, we take a goal-driven modeling approach to understand the development of primary visual cortex. Under the hypothesis that biological maps emerge as a solution to the problem of understanding visual input, we trained a deep convolutional neural network to categorize natural images while respecting the retinotopic constraints present before the onset of visual experience. Formally, units in the model's first convolutional layer were assigned a 2-dimensional spatial position consistent with their receptive fields, and the network was penalized during training if adjacent units differed too strongly in their responses or if distant units had similar responses. Results We evaluated the trained model by presenting structured stimuli—gabor wavelets at specified spatial frequencies, orientations, and positions—and constructing tuning curves over the parameters of interest for units in the first convolutional layer. The map of orientation tuning is strikingly similar to biological findings, with clear iso-orientation domains and pinwheel-like patterns. The spatial frequency tuning map similarly recapitulates many of the features observed in macaques and cats. Conclusion Our results suggest that training a model to solve a challenging visual task—image classification—is sufficient to reproduce maps of orientation and spatial frequency preference in early visual areas. Future work will be needed to determine the developmental program and model architecture required to recapitulate functional maps along the extent of visual cortex.

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43.343 **Body Coding Mechanisms in 9- to 10-Year-Old Children and Young Adults** Astrid Hönekopp[1](astrid.hoenekopp@rub.de), Annika C. Just[2], Sarah Weigelt[1], Kami Koldewyn[3]; [1]Developmental Neuropsychology, Faculty of Psychology, Ruhr-Universität Bochum, [2]Department of Psychology, Leipzig University, [3]School of Psychology, Bangor University

Along with faces, bodies are important social stimuli that provide crucial information we can use for recognizing, understanding, and predicting other people. While a great deal is already known about face processing and face coding in the human brain across development, this is not the case for body processing. Coding of facial identity, for example, has widely been studied with the help of face identity adaptation aftereffect paradigms. In adults and children alike, facial identity seems to be norm-based and opponent coded in a face-space instead of in an exemplar-based, multichannel coding system. Rhodes, Jeffery, Boeing, and Calder (2013) examined body coding mechanisms in adults using a body identity adaptation aftereffect paradigm. Their results provide evidence for norm-based, opponent coding of human bodies. Using a comparable aftereffect paradigm, albeit embedded in a story about a "superhero training camp", the present study investigated body coding mechanisms in young adults and 9- to 10-year-old children. So far, 34 children and 29 adults have been tested with a child-friendly, two-alternative forced choice touch tablet task. Preliminary results suggest that body identity is coded in a body-space in children and adults alike. However, from our data, no clear conclusion can be drawn yet, for either age group, concerning the differentiation between norm-based and exemplar-based coding of body identity. The present study therefore provides the first evidence of similar body coding mechanisms in a body-space for school-aged children and adults. Nonetheless, the exact body identity coding mechanisms at work and both how and when such mechanisms develop remain as open questions.

43.344 **Heritability of the human visual connectome** Koen V Haak[1,2](k.haak@donders.ru.nl), Christian F Beckmann[1,2,3]; [1]Donders Institute for Brain, Cognition and Behaviour, Centre for Cognitive Neuroimaging, Radboud University, Nijmegen, The Netherlands, [2]Department of Cognitive Neuroscience, Radboud University Medical Centre, Nijmegen, The Netherlands, [3]Oxford Centre for Functional Magnetic Resonance Imaging of the Brain (FMRIB), University of Oxford, United Kingdom

Visual perception requires the integrated activity of many functionally distinct cortical visual brain areas, served by an intricate network of cortico-cortical connections. An important open question concerns the degree to which the strength of these connections is under genetic control. In the present work, we derived the resting-state functional connectivity strength between twenty-five cortical visual areas (retinotopic maps) in each cerebral hemisphere of 499 Human Connectome Project (HCP) subjects and leveraged the fact that HCP subjects were drawn from families of twins and their non-twin siblings (60 monozygotic twin-pairs) to estimate the heritability of the visual connection strengths (i.e., h2: the amount of phenotypic variance that can be accounted for by the total additive genetic variance). On average over the entire human cortical visual connectome, genes accounted for roughly 10% of the phenotypic variance, with little difference between intra- and interhemispheric connections, and little difference between connections on the medial, ventral and lateral surfaces of the occipital lobe. The relatively low heritability of the cortical visual functional connectivity strengths suggests that they are determined primarily by the environment and other non-genetic factors, which in turn suggests a potential for brain plasticity in response to, for instance, eye disease.

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43.345 **Malleability of speed accuracy trade-offs across the adult lifespan** Jutta Billino[1](jutta.billino@psychol.uni-giessen.de), Elena Hitzel[1], Constanze Hesse[2]; [1]Department of Psychology, Justus-Liebig-University Giessen, [2]School of Psychology, University of Aberdeen

For a variety of tasks it has been shown that speed-accuracy trade-offs (SAT) shift towards slower speed and higher accuracy with increasing age. However, it has remained controversial whether this shift indicates global slowing based on general neural deficiencies or rather a strategic choice because senior adults prefer to avoid mistakes and thus sacrifice speed voluntarily. We aimed to investigate the malleability of the SAT across the adult lifespan. We applied a manual pointing task for measuring SATs. In a baseline condition, movements were instructed with only moderate speed and accuracy demands. In contrast, in a stress condition strong emphasis was put on speed and challenging timeout criteria were set that were derived for each individual from their baseline performance. In addition, we gave detailed accuracy feedback after each trial. We tested forty-four participants covering an adult age range from 21 to 69 years. As expected, we found an age-related slowing of pointing movements. We determined SATs in baseline and stress conditions using the respective slopes of the functions relating movement times and accuracy. SATs differed significantly between both conditions, indicating an accelerated trading of accuracy for speed in the stress condition. Furthermore, regression analyses revealed that age predicted SATs in the baseline condition. In line with previous findings, we observed that increasing age was linked to a reluctance to adopt fast, but imprecise pointing movements under moderate speed-accuracy requirements. In contrast, SATs in the stress condition were not predicted by age. Our findings suggest that age-related differences in SATs can be attenuated by explicit instructions that emphasise speed and are not exclusively defined by processing resources.

43.346 **Age effects on category rule learning** Clay D Killingsworth[1](ckillingsworth@knights.ucf.edu), Audrey Hill[1], Pooja Patel[1], Anna Guidubaldi[1], Drew Gillett[1], Mark Neider[1], Corey Bohil[1]; [1]Department of Psychology, College of Sciences, University of Central Florida

A growing literature suggests that separate learning systems may be differently affected by cognitive aging. We conducted two experiments comparing young and older adults on category rule learning. In Experiment 1, two-dimensional stimuli (lines varying in length and orientation) were learned according to either an explicit (verbalizable) rule requiring selective attention to one dimension or an implicit rule requiring integration of dimensions. In Experiment 2, participants categorized 4-dimensional color/shape stimuli (a modified Wisconsin Card Sorting Task) according to explicit or implicit rules. In both experiments, accuracy was higher for young adults than for older adults. In both experiments accuracy was higher for rule-based than for information integration categories, and this difference was more pronounced for older adults. In Experiment 2 (card sorting), older adults required more trials to reach an accuracy criterion. Decision bound modeling indicated that a greater proportion of older adults adopted suboptimal decision rule types.

43.347 **How to classify visual illusions? The role of intellectual development.** Aline F. Cretenoud[1](aline.cretenoud@epfl.ch), Lukasz Grzeczkowski[2], Michael H. Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, [2]Allgemeine und Experimentelle Psychologie, Department Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany

Vision scientists have tried to classify visual illusions for a long time. Piaget (1969) proposed that visual illusions can be classified into two groups, depending whether the illusion magnitude decreases or increases with age and intellectual development. These two groups are called primary and secondary illusions, respectively. Contrary to primary illusions, which are supposed to be innate, secondary illusions are thought to be acquired: daily experience with perspective cues enhances our susceptibility to them. Here, we tested illusion magnitudes for the Ponzo and Müller-Lyer illusions with three different complexity levels. We used a classic version of these illusions ("low" complexity), the illusions embedded into line drawing perspective ("intermediary" complexity) and their corresponding real world versions ("high" complexity). A linear model based on data from 86 observers with ages ranging from 6 to 66 years did not reveal any significant effect of the interaction between age and complexity. Illusion magnitudes of the three Müller-Lyer illusions were significantly correlated and the same is true for the Ponzo illusion, suggesting that each illusion makes up its own factor.

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43.348 **The Development of Social Interaction Perception in the Brain** Kami Koldewyn[1](k.koldewyn@bangor.ac.uk), Ioana Mihai[1], Jon Walbrin[1]; [1]School of Psychology, Bangor University

Recent evidence suggests that a region of the posterior superior temporal sulcus (pSTS) may be selective for the perception of social interactions (Isik et al., 2017). The developmental trajectories of other selective social brain responses (i.e. functionally selective regions for the processing of faces, bodies, & theory of mind (ToM) information) have been relatively well-studied, yet little is known about how the perception of interactive behaviour develops from childhood into adulthood. We used fMRI to scan both children (5-12 years) and adults (18 – 35 years) as they viewed videos that allowed us to functionally localize and test responses to interactions in the pSTS. In addition, we used a handful of other localizer scans to identify other regions in the "social brain", including face, body, and ToM selective brain areas. We aimed to characterize how 'adult-like' functional response to perceived social interactions was in these localized regions as well as across the brain using a number of measures (e.g., the magnitude and extent of activation, the selectivity of the response, how well other social information responses predict interaction response). Our preliminary results (in 12 children and 19 adults) suggest that neural measures of interaction perception are not fully mature in children. In particular, the response in the pSTS is less selective in children than adults, and children show evidence of using a wider network of social brain regions than adults when viewing social interactions. These unique findings provide an important first step towards characterizing a developmental model for interaction perception in the brain. In future, these findings may serve as a starting place for better understanding how social brain development may be altered in neurodevelopmental disorders characterized by differences in social response (e.g. autism spectrum disorder, schizophrenia, Williams syndrome).

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43.349 **Development of the contrast sensitivity function** Jessica Tardif[1](jessica.tardif.1@umontreal.ca), Laveniya Kugathasan[2], Frédéric Gosselin[1], Deborah Giaschi[2]; [1]Department of Psychology, University of Montreal, [2]Department of Ophthalmology, University of British Columbia

The development of the Contrast Sensitivity Function (CSF) has been studied many times, but there is no consensus yet as to when sensitivity for different spatial frequencies (SFs) becomes mature. Many methods have been used, many different ranges of SFs have been measured, different age groups have been studied, and results differ greatly between studies. Here, we used an objective psychophysical method to measure the CSF across seven SFs (0.5 to 30 cpd), in 124 individuals between 5 and 28 years of age. All participants viewed Gabor patches on a calibrated computer monitor and completed an orientation discrimination task (vertical vs. horizontal). Distance was kept constant using a chin rest. The FWHM of the Gaussian envelop was 2 degrees of visual angle. Noise-bit dithering (Allard & Faubert, 2008) was applied to every stimulus. Contrast was adjusted across trials (48 trials per SF) independently for each SF, using QUEST (Watson & Pelli, 1982), to reach a target accuracy of 65%. The mean contrast threshold obtained at the end of the QUEST run was used to determine sensitivity for each SF. For all SFs, sensitivity correlated significantly and positively with age (minimal $r=.24$; all p's$<.05$). Next, to determine at what age sensitivity becomes adult-like, we fitted the function If $x< c$, $y = a*x+b$; else, $y = a*c+b$; The parameter c corresponds to the age at which sensitivity stops improving. We found that sensitivity matures around 12-13 years of age, and slightly earlier for low SF than high SF. This result is compatible with past results on the development of low-level vision and what we know about brain maturation.

Acknowledgement: NSERC

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43.350 **Maturation of visuomotor coordination and motion-defined form perception in typically-developing children** Deborah Giaschi[1](giaschi@mail.ubc.ca), Kimberly Meier[2], Violet Chu[1], Pamela Bryden[3], Ewa Niechwiej-Szwedo[4]; [1]Ophthalmology & Visual Sciences, University of British Columbia, [2]Psychology, University of British Columbia, [3]Kinesiology and Physical Education, Wilfrid Laurier University, [4]Kinesiology, University of Waterloo

Introduction. Deficits in motion perception in developmental disorders are commonly attributed to vulnerability in the dorsal visual stream. This attribution is supported by associations between global motion perception and visuomotor skills in preschool children, both typically-developing and those at risk for abnormal neurodevelopment. Our study compared the typical maturation of hand-eye coordination and motion-defined form discrimination, an aspect of motion perception that is deficient in developmental disorders but that has been linked to both ventral and dorsal streams, in a large group of school-aged children. Methods. We assessed 204 children, age 4 to 16 years, in a public science museum setting. Binocular motion coherence thresholds for discriminating the orientation of computer-generated motion-defined rectangles (vertical or horizontal) were measured with a 2-alternative forced-choice staircase procedure. Hand-eye coordination was measured with a pen and paper circle-marking task; the number of circles accurately marked in 20s was determined. Results. Performance on both tasks was similar to that observed in controlled laboratory settings. Motion-defined form perception improved from 4 to 11 years of age, and performance on the circle-marking task improved until 12 years of age. Although motion coherence thresholds were significantly correlated with the number of circles marked, further analyses revealed that this relationship was driven by improvement in performance with age. Conclusion. We did not find an association between the maturation of motion-defined form perception and a measure of fine hand-eye coordination in typically-developing children. These aspects of vision were chosen because they are known to mature relatively late in development, and to be disrupted by conditions such as amblyopia that interfere with binocular vision. We are currently assessing additional measures of visuomotor performance.

Acknowledgement: Natural Science and Engineering Research Council of Canada

43.351 **Multiple object tracking via sustained multifocal attention in children** Tashauna L Blankenship[1](shaunalb@bu.edu), Roger W Strong[2], Melissa M Kibbe[1]; [1]Psychological and Brain Sciences, Arts and Sciences, Boston University , [2]Psychology, Arts and Sciences, Harvard University

Multiple-object tracking (MOT) is the process of maintaining the location of multiple moving objects among distractors. Successful tracking requires flexible endogenous control of attention, an ability that undergoes considerable development throughout middle childhood (Ridderinkhof & van der Stelt, 2000; Rueda et al., 2004). Previous work suggests that 6-year-old children can successfully track up to two targets during a MOT task (Trick, Jaspers-Fayer, & Sethi, 2005). Unclear, however, is whether children have the ability to use sustained multifocal attention to track multiple targets, or instead use strategies that permit tracking with a single focus of attention (Yantis, 1992), such as grouping or serially foveating individual targets. We created a MOT task for children ages 6-7 years (M = 6.67, SD = .52), designed so that tracking using such grouping or switching strategies would be difficult. The task was presented as a game, where the goal was to feed an animal (presented at fixation) its favorite food, represented by dots. On each trial, participants saw four dots presented in two pairs, each consisting of 1 target (the animal's favorite food, indicated by a brief flash prior to object movement) and 1 distractor. The target/distractor pairs began orbiting in diagonally opposite quadrants of the screen, and then shifted either vertically or horizontally to the previously unoccupied quadrants (while continuing to orbit). Children were then probed on one of the pairs and asked to select the target. Because each target was always closely grouped with a distractor, tracking using strategies that require grouping targets or briefly removing attention from targets should be difficult. Nevertheless, participants performed well above chance (50%) levels (M = 95%, $t(5) = 22.70$, $p < .001$). These findings suggest that 6-7-year-olds can track using multifocal attention, and that our tracking task can be used to study the development of this ability.

43.352 **Visual temporal integration windows are adult-like in typically developing 5-7-year-old children.** Julie Freschl[1](julie.freschl001@umb.edu), David Melcher[2], Zsuzsa Kaldy[1], Erik Blaser[1]; [1]University of Massachusetts Boston, [2]University of Trento, Center for Mind/Brain Sciences

The visual system receives a flow of information that must be organized, over time, into objects, scenes, and events, balancing between stable representations and sensitivity to change. If two events fall within the same Temporal Integration Window, they are integrated; if they fall in different windows, they are segmented (TIW; Wutz et al., 2016). We measured TIWs in typically developing 5-7-year-old children (N=29), and adults (N=36). To the best of our knowledge, this is the first explicit, developmental investigation of visual TIWs. On each trial, participants were presented with a sequence of two 17ms displays (with four such displays, in an ABAB pattern, for children; AB for adults) separated by an Inter-Stimulus Interval (ISI) of 17, 67, 83, or 117 ms. Display A contained seven circles and one half-circle, randomly placed within a virtual 4x4 grid. Display B contained the same elements, but with the circles occupying previously empty locations, and, importantly, the half-circle occupying the same location as in Display A (and with a complementary orientation (adapted from Di Lollo, 1980; see Figure)). Between the two displays, then, 15 of the 16 locations were occupied by elements. This yielded two potential 'targets'. If (and only if) A/B are segmented, the half-circle segmentation target becomes apparent; if A/B are integrated, the empty-location integration target becomes apparent. Depending on block, participants were instructed to locate either the integration or the segmentation target, by pointing (children), or clicking (adults). Longer ISIs increased the likelihood of segmentation, thereby decreasing performance on integration-target trials, but increasing performance on segmentation-target trials, allowing us to pinpoint an individual's TIW by measuring the 'crossover point' where these two functions intersect. Children's TIWs (M=55 ms, SD=21) were indistinguishable from adults' (M=53 ms, SD=25), indicating that TIWs reach adult levels by at least 5-7 years of age.

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43.353 **Investigating the development of the human visual system with fMRI in awake, behaving infants** Cameron T Ellis[1](cameron.t.ellis@hotmail.com), Lena J Skalaban [1], Natalia I Cordova[2], Javier S Turek[3], Vikranth R Bejjanki[4], Nicholas B Turk-Browne[1]; [1]Department of Psychology, Yale University, [2]Department of Psychology, Princeton University, [3]Parallel Computing Lab, Intel Labs, [4]Department of Psychology, Hamiliton College

Vision undergoes rapid and dramatic development early in life. These changes have been investigated extensively with behavioral techniques, but there is a dearth of direct neural studies of the developing visual system. This stands in contrast to the adult visual system where a great deal has been learned over two decades by using fMRI, including studies of retinotopy, attention, and perceptual learning. The lack of fMRI studies in infants and toddlers reflects the technical complexity of performing such experiments, including head motion, attention span and fussiness, inability to understand or follow instructions, uncomfortable apparatus, and adult-centric analysis approaches. When infants have been scanned successfully, it has typically been during sleep or sedation, preventing the kinds of cognitive tasks that would allow for comparisons to adults and for benefitting from the tremendous advances in adult cognitive neuroscience. Here we report on our attempts to re-imagine task-based fMRI procedures for early developmental populations. The resulting advances include: projector-based panoramic visual presentation, flexible experiment transitions, within-volume motion artefact detection and functional alignment. With these procedures, we have now scanned 18 participants under the age of 36 months and retained a high percentage of the functional data collected from each participant. These procedures also produce reliable evoked BOLD activity in visual cortex in response to a wide variety of visual stimuli. With these tools in hand, we are now investigating the retinotopic organization, attention networks, and plasticity of the infant visual cortex. Each of these studies presents its own unique

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challenges, such as the difficulty ensuring fixation during retinotopy. Nevertheless, the hope is to complement the wealth of work on visual development with a detailed understanding of early brain function.

43.354 The psychophysics of newborn infant vision assessment Angela M Brown[1](brown.112@osu.edu), Faustina O Opoku[1], Delwin T Lindsey[1,2]; [1]College of Optometry, Ohio State University, [2]Department of Psychology, Ohio State University

This research was prospectively designed to determine whether the contrast sensitivity function of the newborn infant was low-pass or bandpass, and whether contrast sensitivity could be accurately measured using an 0.083 cy/deg (20/7200) square-wave stimulus. The results were retrospectively analyzed to determine whether our two data-collection protocols—the Method of Constant Stimuli (MCS) and the descending Method of Limits (dLIM)—yielded similar results. Methods: Infant visual performance was measured using a card-based fixation-and-following technique and a yes-no psychophysical paradigm. In across-subjects experimental designs, a pilot study used MCS (N=47 visual acuity; N=40 contrast sensitivity at 0.083 cy/deg), and a main experiment used dLIM (N=22 visual acuity; N=21 contrast sensitivity at 0.083 cy/deg; N=21 at 0.301 cy/deg), to measure the visual performance of healthy newborn infants in a hospital postpartum unit. Two low-pass and one bandpass contrast sensitivity functions estimated the peak neonatal contrast sensitivity. Psychometric functions from the MCS and dLIM data sets were compared while taking the stimulus presentation protocols into account. Results: In the main experiment, the bandpass contrast sensitivity function fit the data best. However, the 0.083 cy/deg square wave stimulus underestimated the best performance of newborn infants by only 0.15 log10 units or less for all three candidate contrast sensitivity functions. MCS produced numerically slightly higher sensitivity, but MCS and dLIM data agreed closely when analyzed to take the stimulus presentation contingencies into account. The MCS and dLIM results are more similar when larger between-stimulus step sizes are used. Conclusions: The contrast sensitivity function of the newborn infant is bandpass. Newborn contrast sensitivity is well measured using a 0.083 cy/deg square wave target, regardless of which contrast sensitivity function is correct. MCS and dLIM yield wholly comparable results, with no evidence of influence from other factors such as infant inattention or examiner impatience.

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43.355 Development of Pursuit of a Random Walk by Infants aged 4 to 17 Week Colin O Downey[1](colodown@indiana.edu), Griffin C Pace[1], Larry K Cormack[2], Scott B Stevenson[3], Tracey Rowan Candy[1]; [1]Indiana University, [2]University of Texas at Austin, [3]University of Houston

Purpose: Pursuit eye movements develop rapidly during the first four months postnatally (Shea & Aslin, 1990) with increased gain and response duration (Phillips et al, 1997). Previous studies have used horizontal, sinusoidal motion of different speeds and amplitudes (Jacobs et al, 1997; von Hofsten & Rosander, 1996), but none have used a random unpredictable trajectory. This study documented development of pursuit movements of infants 4-17 weeks of age, using a cross-correlogram approach (Mulligan et al, 2013). Methods: Twelve infants and ten adults were presented with a white 4deg square moving randomly in velocity on a rear projection screen in horizontal, vertical, oblique, or 2-dimensional paths for 100s. Eye position was recorded binocularly using an Eyelink 1000 (SR Research) at 500Hz. Results: Cross-correlations between the stimulus and response positions and velocities demonstrated pursuit in infants as young as 4wks of age for horizontal and vertical profiles. Median adult latencies to peak correlation were 0.674sec (IQR: 0.638-0.715sec) for position and 0.708sec (IQR 0.670-0.755sec) for velocity, while the overall infants' medians were 1.07sec (IQR 0.328-1.432sec) for position and 1.07sec (IQR 0.152-1.370sec) for velocity. Median peak correlations were similar for adults across conditions (pos = 0.972, IQR 0.947-0.984; vel = 0.629, IQR 0.540-0.704), while median peak correlations were higher for infants for the 1-dimensional vertical and horizontal movements than the oblique and 2-dimensional movements (pos. = 0.912, IQR 0.751-0.942 (x&y); 0.818, IQR 0.502-0.874 (oblique); 0.414, IQR 0.137-0.770 (2D) & vel. = 0.399, IQR 0.242-0.462 (x&y); 0.286, IQR 0.215-0.328 (oblique); 0.234, IQR 0.184-0.299). Conclusion: These data indicate that infants as young as 4wks can pursue a random target motion, though with longer latency than adults and an apparent effect of trajectory complexity. Our longitudinal data suggest immaturities lasting beyond 17wks of age.

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43.356 Infants' detection of self-shadow change and object's shape change Kazuki Sato[1](kazukisato@hotmail.com), So Kanazawa[2], Masami K. Yamaguchi[1]; [1]Chuo University, [2]Japan Women's University

Human ignore changes due to environment to perceive a constant object. For example, previous studies showed that adults ignored changes in shadows implicitly. However, the development of this ability is still an open question. Recently, Yang et al. (2015) found that 7-to-8-month-old infants could detect changes in materials of objects. In contrast, 3-to-4-month-old infants could detect changes in light-field caused by illumination changes better than adults and 7-to-8-month-olds. These results suggested that infants in pre-constancy have an ability to discriminate local changes that adults ignore. In our study, we investigated whether infants aged 3-to-8-months could detect changes in self-shadow of objects by using a change-detection paradigm. We presented changing image and non-changing image sequences side by side. Each sequence consisted of two images, and all images were flashed in rapid alternation with an interstimulus interval (ISI). We hypothesized that infants would prefer to the changing image sequence if they could detect changes of image property. We set two conditions for different changing image sequence; the shadow-change condition and the shape change condition. In the self-shadow change condition, an image pair consisted of images rendered from a same object with different illumination direction. In the shape change condition, an image pair consisted of images rendered from two objects with different three-dimensional structure. In the non-changing image sequence, the same image of object was presented repeatedly. Results revealed that 7-to-8-month-olds looked longer to the changing image sequence than non-changing image sequence only in the shape change condition. In contrast, 3-to-4-month-olds show the preference for the changing image sequence only in the shadow change condition. These results suggest that 7-to-8-month-old infants could not detect the changes in object's self-shadow but can detect the changes in three-dimensional structure, whereas 3-to-4-month-olds could detect local changes in images that are not salient for 7-to-8-month-olds.

43.357 Infants' ability to detect and learn faces during rapid serial visual presentation Shuma Tsurumi[1](perry.super178@gmail.com), So Kanazawa[2], Masami K Yamaguchi[1], Jun Kawahara[3]; [1]Department of Psychology, Chuo University, [2]Department of Psychology, Japan Women's University, [3]Department of Psychology, Hokkaido University

Previous studies mentioned that infants would detect the face presented for short duration; 5- and 10-month-olds perceive the face presented for 150 ms followed by mask (Gelskov and Kouider, 2010), and 5-month-olds learned the face presented for 100 ms without mask (Lasky and Spiro, 1980). However, these studies have not elucidated infants' ability to detect the face in rapid serial visual presentation (RSVP) sequence, which pictures mask each other. In this study, we investigated the infants' ability to perceive and learn a face in an RSVP sequence. The purpose of Experiment 1 was to examine whether 5- to 8- month-olds perceive various pictures presented for 100 ms, adults could perceive. Infants were presented with two RSVP sequences of a series of 15 pictures presented for 11 or 100 ms per picture with no interstimulus interval side by side. We hypothesized that if infants perceive each picture presented for 100 ms, they would prefer 100-ms sequences. We tested this by comparing the looking time to each sequence. Results showed that only 7- and 8-month-olds preferred the 100-ms sequence. In Experiment 2, to examine whether 5- to 8- month-olds detect the face presented for 100 ms, two RSVP sequences in each which contained an upright (or inverted) face were presented side by side, and infants' preference to upright face was measured. In this experiment, 7- and 8- month-olds preferred the RSVP sequence containing upright faces, suggesting that these infants detect the faces. In Experiment 3, to further clarify the face processing in infants, we tested whether infants could learn faces in RSVP sequences. The results

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indicated that 7- and 8- month-olds learned the faces during the RSVP. In sum, our results indicate that 7- and 8- month-olds perceive and learn the face in RSVP sequences.

43.359 **Maternal odor shapes rapid face categorization in the 4-month-old infant brain** Arnaud Leleu[1](arnaud.leleu@u-bourgogne.fr), Diane Rekow[1], Fanny Poncet[1], Bruno Rossion[2], Karine Durand[1], Benoist Schaal[1], Jean-Yves Baudouin[1]; [1]Group "Developmental Ethology and Cognitive Psychology", Centre des Sciences du Goût et de l'Alimentation, AgroSup Dijon, CNRS, INRA, Université Bourgogne Franche-Comté, F-21000 Dijon, France, [2]Psychological Sciences Research Institute and Institute of Neuroscience, Université catholique de Louvain (UCL), 1348 Louvain-la-Neuve, Belgium Service de Neurologie, Centre Hospitalier Universitaire de Nancy, 54035 Nancy, France

To interact with an unlabeled rich visual world, the human developing brain learns to differentiate visual events and to generalize across some of them despite their physical variability. Although this perceptual categorization process has been traditionally investigated from a unisensory perspective, the early development of visual categorization is inherently constrained by multisensory inputs. In particular, the visual system being largely immature in infancy, early-maturing sensory systems such as olfaction are ideally suited to support and refine visual development. Odors are relevant cues for young infants providing stability and familiarity within a rapidly changing complex visual environment. Here we provide evidence that perceptual categorization of one of the earliest and most salient visual category for the young infant brain, human faces, is shaped by a familiar odor already learned in utero, the maternal odor. We recorded scalp electroencephalogram (EEG) from 18 four-month-old infants exposed to the maternal or a control odor condition during rapid 6 Hz stream of widely variable natural images, with faces inserted every 6th image (i.e., at 1 Hz). We replicate the infant brain ability to categorize at a glance various faces embedded in a fast train of natural images, with a significant face categorization response at 1 Hz over right posterior cortical regions (de Heering & Rossion, 2015). Strikingly, this visual categorization response is enhanced by concomitant maternal odor inputs, with every single infant brain showing a larger face categorization response in the maternal odor context. The lack of difference between odor conditions for the 6 Hz visual response common to all images excludes a mere enhancement of visual attention in the maternal odor context. Overall, these observations support a multisensory view of category learning and have important implications for our understanding of the development of perceptual categorization in the human brain.

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Multisensory Processing: Vision, vestibular, models

Monday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

43.360 **Experimentally disambiguating models of sensory cue combination** Peter Scarfe[1](p.scarfe@reading.ac.uk), Andrew Glennerster[1]; [1]School of Psychology and Clinical Language Sciences, University of Reading, UK.

When combining information to estimate properties such as size, depth and shape, observers are thought to combine cues optimally in proportion to their relative reliabilities in order to minimise the variance of the combined cues percept (Landy, Maloney, Johnston and Young, 1995). However, experimental tests of optimal cue combination rarely test performance relative to other candidate models (e.g. 'cue veto', 'go with most reliable cue', or 'probabilistic cue switching'). This is problematic as, for a wide range of relative reliabilities, the predictions of these models are very similar to one another. Here, we present Monte-Carlo simulations of end-to-end experiments in which the simulated observers performed in accordance with the predictions of an optimal cue combination model. We varied the relative reliability of the available cues, the number of simulated observers and parameters of the experimental psychometric procedure, such as sampling of the psychometric functions, in each case, fitting the simulated data with a cumulative Gaussian. By comparing the performance of our simulated optimal observers with the predictions from the alternative candidate models we calculated the proportion of times these alternative models could be rejected. We find that models are maximally distinguishable when the available cues have equal reliabilities and, of course, when number of participants per experiment increases. Models such as 'probabilistic cue switching' are easier to reject than 'go with most reliable cue' and 'cue veto'. We examine a series of published studies that claim to support optimal cue combination and report on their ability to actually distinguish between alternative models. This analysis allows us to specify the way in which experiments should be designed if they aim to distinguish between candidate models of reliability in sensory cue combination.

43.361 **Differential processing delays cause the onset of the rod-and-frame illusion to precede the onset of the frame** Jeffrey M Peterson[1](jpeters7@uoregon.edu), Paul Dassonville[1]; [1]Department of Psychology, University of Oregon

Orientation judgments are made within a reference frame that is greatly dependent on the vestibular system, but the visual system is also able to extract contextual cues from a viewed scene (e.g., vertical door frames, horizontal desktops). This becomes dramatically apparent when prominent cues are misleading, as in the case of the rod-and-frame illusion (RFI, Asch & Witkin, 1948), where a tilted frame causes a distortion in the egocentric reference frame, such that an enclosed rod is perceived as being rotated in the opposite direction. Past studies of the RFI have documented the manner in which contextual cues are incorporated into an observer's reference frame, but the time course of this effect remains unclear. To characterize this time course, we used a variation of the RFI which included a temporal mismatch between the onset of a tilted frame (±15°) and the occurrence of a briefly flashed rod (5ms duration, presented in a range of times from 200ms before to 200ms after frame onset). In otherwise complete darkness, participants compared the tilt of the rod to subjective vertical. There was no effect of the frame when the rod was presented well before (200ms) frame onset, and the effect reached a maximum plateau for rods presented simultaneous with frame onset or later. In between these extremes, the effect grew in size, becoming significant even for rods extinguished ~128ms before frame onset. An effect of the frame that precedes the frame's actual onset can be explained by a difference in the processing delays for 1) the orientation judgment task and 2) the context-driven distortion of the egocentric reference frame. The pattern of findings reported here indicate that the orientation judgment takes approximately 130 ms longer than the delay in the egocentric distortion.

43.362 **Dynamics of spatial updating during whole-body passive translation** Florian Perdreau[1](f.perdreau@donders.ru.nl), Pieter W Medendorp[1]; [1]Radboud University Nijmegen, Donders Institute for Brain, Cognition & Behaviour

Positions of objects shift on our retina every time we move, which leads to the ambiguous situation that retinal inputs can be attributed to a change in either the object position or our own position. To disambiguate the sensory input, the brain must account for the amplitude and direction of self-motion and update objects positions accordingly. Spatial updating has been mostly investigated in a discrete fashion, where participants are asked to compare the pre- to post-movement target positions. Therefore, little is known about the dynamics of spatial updating during the intervening motion, which may depend on the available sensory signals. The otolith organs are the linear acceleration sensors. Because the strength and quality of their signal depends on the dynamics of the motion, we hypothesized that the quality of updating would be affected accordingly. To test this hypothesis, we used an apparent motion illusion during whole-body passive translation. While participants were moved with a bell-shaped velocity profile in complete darkness, two dots were briefly and successively flashed, one above and one below a body-fixed fixation target, thereby inducing the perception of a single dot moving. This illusion could be presented at the time of peak acceleration, peak velocity or peak deceleration of the body motion, and participants were asked to report its orientation relative to vertical. Individual updating gains show an underestimation of displacement regardless of the tested phase of the translation. Furthermore, the updating gain was higher at peak acceleration than at peak velocity and peak deceleration. This pattern was systematically observed, regardless of whether the time interval or the traveled distance between the presentation of the two stimuli were matched. Our

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results provide a dynamic characterization of spatial updating during body motion, thereby unveiling an asymmetry in how acceleration and deceleration signals are incorporated in the underlying computations.

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43.363 **Sensitivity to visual gain modulation in head-mounted displays depends on fixation** Matthew J Moroz[1](mmoroz@nevada.unr.edu), Garzorz Isabelle[2], MacNeilage Paul[1], Folmer Eelke[3]; [1]Psychology Department, University of Nevada, Reno, [2]Systemic Neurosciences, Ludwig Maximilian University of Munich, [3]Computer Science Department, University of Nevada, Reno

A primary cause of simulator sickness in head-mounted displays (HMDs) is the rendering of visual scene motion that does not match head motion. Agreement between visual scene motion and head motion can be quantified based on their ratio which we refer to as visual gain. We suggest that it is useful to measure perceptual sensitivity to visual gain modulation in HMDs (i.e. deviation from gain=1) because conditions that minimize this sensitivity may prove less likely to elicit simulator sickness. In prior research, we measured sensitivity to visual gain modulation during slow, passive, full-body yaw rotations and observed that sensitivity was reduced when subjects fixated a head-fixed target compared with when they fixated a scene-fixed target. In the current study, we investigated whether this pattern of results persists when 1) movements are faster, active head turns, and 2) visual stimuli are presented on an HMD rather than on a monitor. Subjects wore an Oculus Rift CV1 HMD and viewed a 3D scene of white points on a black background. On each trial, subjects moved their head from a central position to face a 15 deg eccentric target. During the head movement they fixated a point that was either head-fixed or scene-fixed, depending on condition. They then reported if the gain applied to the visual scene motion was too fast or too slow. Gain on subsequent trials was modulated according to a staircase procedure to find the gain change that was just noticeable. Sensitivity to gain modulation during active head movement was reduced during head-fixed fixation, similar to what we observed during passive whole-body rotation. We conclude that fixation of a head-fixed target is an effective way to reduce sensitivity to visual gain modulation in HMDs, and may also be an effective strategy to reduce susceptibility to simulator sickness.

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43.364 **Perceived size during visually simulated self-motion** JongJin Kim[1](johnk84@yorku.ca), Laurence R Harris[1]; [1]York University

INTRODUCTION The perceived distance to objects in the environment needs to be updated during self-motion. Such updating needs to be overridden if the object moves with the observer (such as when reading a phone while walking). Errors in updating could lead to errors in perceived distance and, because of size/distance invariance, to errors in perceived size. To look for such errors, we measured the perceived size of an object that moved with the observer during visually simulated self-motion. METHODS Participants judged whether a vertical rod presented on the ground plane in a virtual-reality-simulated scene at a fixed distance of 2-10m, was longer or shorter than a physical rod (45cm) that they held in their hands either vertically or horizontally. Observers were either stationary or in the presence of optic flow compatible with moving at 1m/s or 10m/s forwards or backwards. Viewing was monoscopic or stereoscopic. Responses were fitted with a logistic to determine the PSE. RESULTS The rod generally needed to be larger than the physical rod to be judged as equal to its size. Errors were smaller when viewing monoscopically compared to stereoscopically (+16%). The orientation of the reference rod influenced size judgements, with larger errors when held horizontally (+16%) compare to when held vertically (+6%). However, there were no significant differences observed in the errors in perceived rod size due to optic flow. CONCLUSION We interpret the changes in the perceived size as resulting from an error in perceived distance. Thus, we confirm the well-known observation that perceived distances are compressed in a virtual environment. However, this compression effect disappeared with monoscopic viewing, despite fewer cues to distance. Our ability to update the distance of an object moving with us appears to be robust during forward and backward self-motion.

43.365 **Gender bias in the influence of gravity on perception** Laurence Harris[1](harris@yorku.ca), Sandra Felsner[2], Michael Jenkin[1], Rainer Herpers[2], Alexandra Noppe[3], Timo Frett[3], David Scherfgen[2]; [1]Centre for Vision Research, York University, Toronto, Canada, [2]Institute of Visual Computing at Bonn-Rhein-Sieg University of Applied Sciences, Sankt Augustin, Germany , [3]German Aerospace Center (DLR), Institute of Aerospace Medicine, Cologne, Germany

Females are influenced more than males by visual cues during many spatial orientation tasks; but females rely more heavily on gravitational cues during visual-vestibular conflict. Are there gender biases in the relative contributions of vision, gravity and the internal representation of the body to the perception of upright? And might any such biases be affected by low gravity? 16 participants (8 female) viewed a highly polarized visual scene tilted ±112° while lying supine on the European Space Agency's short-arm human centrifuge. The centrifuge was rotated to simulate 24 logarithmically spaced g-levels along the long axis of the body (0.04-0.5g at ear-level). The perception of upright was measured using the Oriented Character Recognition Test (OCHART). OCHART uses the ambiguous symbol "p" shown in different orientations. Participants decided whether it was a "p" or a "d" from which the perceptual upright (PU) can be calculated for each visual/gravity combination. The relative contribution of vision, gravity and the internal representation of the body were then calculated. Experiments were repeated while upright. The relative contribution of vision on the PU was less in females compared to males ($t=-18.48$, $p \leq 0.01$). Females placed more emphasis on the gravity cue instead (f:28.4%, m:24.9%) while body weightings were constant (f:63.0%, m:63.2%). When upright (1g) in this and other studies (e.g., Barnett-Cowan et al. 2010, EJN, 31,1899) females placed more emphasis on vision in this task than males. The reduction in weight allocated by females to vision when in simulated low-gravity conditions compared to when upright under normal gravity may be related to similar female behaviour in response to other instances of visual-vestibular conflict. Why this is the case and at which point the perceptual change happens requires further research.

Acknowledgement: This project

Perceptual Organization: Contours and surfaces

Monday, May 21, 8:30 am - 12:30 pm, Banyan Breezeway

43.366 **The Motion-Induced Contour Revisited: Rotations in depth reveal novel illusory contours** Gideon P. Caplovitz[1](gcaplovitz@unr.edu), Gennady Erlikhman[1]; [1]Department of Psychology, University of Nevada Reno

Victor Klymenko and Naomi Weisstein first described the Motion-Induced Contour (MIC) in 1980. In their original demo, a tilted wire cube is shown with one of its vertical edges removed. When the cube is set in motion, rotating in depth back and forth about its vertical axis, an illusory contour is perceived in the position of that missing edge. These displays are interesting because the illusory contours can be nearly orthogonal to the inducing, real edges, unlike most illusory contour displays. Although related to structure-from-motion and stereokinetic contours, MICs have several important differences. Through a series of papers, Klymenko and Weisstein concluded that the perception of the contour depends on a 3-D surface interpretation: structure-from-motion, a rigidity constraint, and is not simply due to rotation or motion in depth but rather 3D rotation through depth. Inspired by their work, we have for the first time in nearly 40 years recreated their original stimuli and have created several novel variants of their original illusion that challenge the initial conclusions and place new constraints on current models of illusory contour formation. We show that (1) unlike other types of illusory contours, MICs are minimally affected by scene context. This allows illusory contours to be observed in 'empty-space' between structure-from-motion induced surfaces. (2) Only the motion of the real contours needs to be rigid – non-rigid MICs can be formed. (3) Some MIC displays are bi-stable, so that perceived global motion changes as a function of perceived depth arrangement of the real

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edges, and this in turn can determine whether or not MIC's are observed, and (4) minimal displays with only two or four edges also produce illusory surfaces, which are sometimes attached to only a single real contour.

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43.367 **How texture elements are combined to detect boundaries: A machine learning approach** Christopher J DiMattina[1](c-dimattina@fgcu.edu), Curtis L Baker[2]; [1]Computational Perception Laboratory, Department of Psychology, Florida Gulf Coast University, [2]McGill Vision Research, Department of Ophthalmology, McGill University, QC, Canada

Natural boundaries are defined not only by differences in first-order cues such as luminance and color, but also by second-order cues such as contrast and texture. However it remains poorly understood how second-order boundaries are represented in the visual system. Here we introduce a machine learning approach to modeling psychophysical performance with second-order boundaries. We address how texture information is integrated across space, and across multiple orientations of texture elements. Pairs of Gabor micropattern textures having differing texture contrasts were quilted to create texture-boundary stimuli. Subjects performed a 2AFC task to distinguish whether texture contrast boundaries were left- vs right-oblique, using a method of constant stimuli to measure (1) threshold modulation depth, for +/- 45 degree boundary orientations, and (2) orientation discrimination for near-horizontal boundaries. Our model consisted of an initial array of fine-scale nonlinear subunits (V1-like filters) whose responses are combined as weighted sums (second-stage filters) which compete to produce the alternative responses of each 2AFC trial. Machine learning methods were used to fit the weights to trial-wise psychophysical data. The fitted models could accurately predict human performance on novel stimulus sets not used for parameter fitting. The estimated second-stage filters indicate that subjects utilize information throughout the entire extent of the stimuli in the modulation depth task, but only use texture elements near the boundary for orientation discrimination - in both cases, like an ideal observer. In additional experiments with carrier textures containing multiple orientations, we observed better fits to data with an "orientation-opponent" model where second-stage filters integrate across multiple first-order orientation channels, than with a "non-opponent" model where second-stage filters only analyze a single orientation channel. This work demonstrates the potential of machine learning methods for modeling second-order boundary perception, an important visual task which cannot be characterized using standard linear modeling techniques.

Acknowledgement: Canadian NSERC grant OPG0001978 to CB, and an internal FGCU Professional Development Grant to CD.

43.368 **Examining the influence of edge length, distance, and orientation on the Motion-Induced Contour** Mengzhu Fu[1](mengzhufu@gmail.com), Gennady Erlikhman[2], Gideon P Caplovitz[2], Michael D Dodd[1]; [1]Department of Psychology, University of Nebraska - Lincoln, [2]Department of Psychology, University of Nevada - Reno

Klymenko and Weisstein (1980) were the first to report the percept of an illusory contour that occurs when individuals observe an animation of a wire-cube—with one of its vertical edges removed—rotating in depth back-and-forth along its vertical axis. As the cube rotates it creates the impression that the missing vertex is visible: the Motion-Induced Contour. In a series of experiments, Klymenko and Weisstein examined the boundary conditions for perceiving the contour. Critically, even in the absence of the entire cube, a Motion-Induced Contour can be observed by aligning two vertices like a pair of chevrons and rotating them in depth such that they resemble the open spine of a book. Here, we revisit the original Motion-Induced Contour illusion using insights gained from research on illusory contours and structure from motion since the initial discovery. In a manner analogous to the definition of the 'support ratio' for stationary Kanisza figures, we sought to determine the relationships between the lengths of the explicit contours in the MIC stimuli, their distance to each other, and the subjective strength of the Motion Induced Contours. Participants viewed a series of displays containing two inducing vertices that rotated in depth along their vertical axis. Vertex-length, the distance between vertices, and the orientation of the inducers were manipulated as participants judged the strength of the illusory contour perceived. Object orientation had no impact on the strength of the illusion, but both vertex-length and the distance between vertices influenced the illusory percept. Specifically, the strength of the illusion increases as a function of the length of the vertices and decreases as a function of the distance between the vertices. These results additional insight into the processes influencing illusory contours in addition to clarifying the relationship between motion-induced contours and related illusions.

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43.369 **Detecting mean shift integrality using the Hering illusion: initial results using general recognition theory and systems factorial theory** Michael Wenger[1](michael.j.wenger@ou.edu), Douglas Bryant[1], James Townsend[2], Ru Zhang[2, 3], Yanjun Liu[2]; [1]The University of Oklahoma, [2]Indiana University, [3]The University of Colorado

General recognition theory (GRT; Ashby & Townsend, 1986) and its reaction time (RT) based extensions (Townsend, Houpt, & Silbert, 2012) offer a number of theoretical and empirical strengths with respect to understanding "configural" or "holistic" perception. One difficulty that has arisen is the question of whether a phenomenon known as mean shift integrality (MSI) might pose challenges to the identification of violations of perceptual and/or decisional separability. Unfortunately, there have been no methods available for ascertaining whether MSI might be occurring. The present project represents an initial to address this problem by inducing MSI using a visual illusion. Observers (n = 6) viewed stimuli designed to induce the Hering illusion (see Figure 1, supplmental materials) in two tasks. The first was a complete identification (CID) task, in which observers indicated perceived curvature of vertical lines presented to the left and right of center. Three levels of induced curvature for each set of lines were combined factorially to produce nine alternatives, with each assigned a unique response. The second task was a double-factorial paradigm (DFP) task in which observers gave one response if they perceived both sets of lines to have the highest possible level of curvature and gave a second response to all of the other stimuli. Sufficient trials were run to allow analysis at the individual observer level. Data from the CID task were analyzed using both frequency- and RT-based measures of marginal response invariance and report independence, and the identification/confusion matrixes were used to fit multivariate gaussian identification models. Data from the DFP task were analyzed using the distribution-based measures of processing architecture and capacity (Townsend & Wenger, 2004). Results indicated that MSI was induced for a subset of the observers, and that there were regularities relating measures of capacity to the presence or absence of MSI.

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43.370 **EEG Correlates of Contour Integration in Younger and Older Adults** Allison B Sekuler[1,2,3](allisonsekuler@mac.com), Eugenie Roudaia[3], Ali Hashemi[3], Jessica N Cali[3], Patrick J Bennett[3]; [1]Rotman Research Institute, Baycrest Health Sciences, [2]Department of Psychology, University of Toronto, [3]Department of Psychology, Neuroscience & Behaviour, McMaster University

Detecting Gabor-defined contours in cluttered backgrounds requires integrating local orientation information across space. Older adults require longer stimulus durations than younger adults to integrate contours in dense clutter, although both groups are similarly affected by changes in contour element collinearity, with performance declining as collinearity decreases (Roudaia et al., 2013). Several EEG studies with younger adults have shown that contour grouping requires top-down information from parietal cortex and LOC to early visual areas (e.g., Volberg & Greenlee, 2014). Here, we examined EEG activity during a contour integration task in 12 younger and 12 older adults (mean ages 22.8 and 66.4 years) under single- and dual-task conditions. Stimuli comprised spiral-shaped Gabor contours embedded within an array of randomly-oriented Gabors, and contour salience was manipulated with 5 levels of collinearity. On each trial in the single-task condition, participants reported the quadrant containing the spiral contour's tail; in the dual-task condition, participants also reported the quadrant of a high-contrast element among background Gabors. As expected, contour discrimination performance varied with collinearity in both groups. The addition of a secondary task did not affect contour discrimination in the younger group, but significantly reduced

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performance in the older group. The pattern of event-related potentials did not differ between the single- and dual-task conditions, but differed across groups: Younger, but not older adults, showed an occipital positivity ~120 ms post stimulus-onset; both groups showed a strong occipital negativity at ~170 ms, with significantly greater amplitude for older adults; younger adults then showed a large positivity at ~300 ms, which was not apparent in older adults. The groups also differed in scalp distribution during the pre-stimulus interval, with younger adults showing a frontal positivity and occipital negativity, and older adults showing the reverse. Results suggest that the neural processes underlying contour integration change with age.

Acknowledgement: CIHR, NSERC, Canada Research Chairs Program, Sandra A. Rotman Chair in Cognitive Neuroscience

43.371 **Does cultural background influence a viewer's Muller-Lyer illusion?** Milena Krstic[1](krsticmia@gmail.com), Zili Liu[1]; [1]University of California, Los Angeles

Purpose. It has been postulated that East Asians and European Americans visually perceive differently. Namely, object perception of East Asians is hypothesized to be influenced more by the object's context than European Americans. We investigated this question using the Muller-Lyer illusion. Method. Two Muller-Lyer figures were presented side by side. The left one always had its fins vertically oriented (90 deg). The right one had all its fins oriented either inward (30 and 60 deg), vertical (90 deg), or outward (120 and 150 deg). The right figure was either shorter or longer than the left one. Participants decided which was longer, and d' and bias were calculated. Participants. Data were collected at UCLA, with undergraduate participants who were either European Americans (42), East Asian Americans (57), East Asians (32), Hispanic Americans (42), or others (66). Results. A 2 x 2 ANOVA on the d' data only revealed a main effect of the fin orientation of the right figure ($p < 0.001$), however there was no main effect of culture ($p = 0.21$). A similar ANOVA on the bias data revealed a main effect of the fin orientation ($p < 0.001$) as expected, but the main effect of culture was not significant ($p = 0.25$). Conclusions. The Muller-Lyer illusion caused both a reduction of discrimination sensitivity and a criterion shift. However, we did not find any difference between participants from different cultural backgrounds.

43.372 **Comparing the ability of humans and DNNs to recognise closed contours in cluttered images** Christina M Funke[1,2,7](christina.funke@uni-tuebingen.de), Judy Borowski[1,2,6,7], Thomas S. A. Wallis[1,2], Wieland Brendel[1,2], Alexander S. Ecker[1,2,3,4], Matthias Bethge[1,2,3,4,5]; [1]Centre for Integrative Neuroscience , Eberhard Karls Universität Tübingen, [2]Bernstein Center for Computational Neuroscience, Tübingen, Germany, [3]Center for Neuroscience and Artificial Intelligence, Baylor College of Medicine, Houston, USA, [4] Institute for Theoretical Physics, University of Tübingen, [5]Max Planck Institute for Biological Cybernetics, Tübingen, Germany, [6]International Max Planck Research School for Intelligent Systems, Tübingen, [7] First authorship shared equally

Given the recent success of machine vision algorithms in solving complex visual inference tasks, it becomes increasingly challenging to find tasks for which machines are still outperformed by humans. We seek to identify such tasks and test them under controlled settings. Here we compare human and machine performance in one candidate task: discriminating closed and open contours. We generated contours using simple lines of varying length and angle, and minimised statistical regularities that could provide cues. It has been shown that DNNs trained for object recognition are very sensitive to texture cues (Gatys et al., 2015). We use this insight to maximize the difficulty of the task for the DNN by adding random natural images to the background. Humans performed a 2IFC task discriminating closed and open contours (100 ms presentation) with and without background images. We trained a readout network to perform the same task using the pre-trained features of the VGG-19 network. With no background image (contours black on grey), humans reach a performance of 92% correct on the task, dropping to 71% when background images are present. Surprisingly, the model's performance is very similar to humans, with 91% dropping to 64% with background. One contributing factor for why human performance drops with background images is that dark lines become difficult to discriminate from the natural images, whose average pixel values are dark. Changing the polarity of the lines from dark to light improved human performance (96% without and 82% with background image) but not model performance (88% without to 64% with background image), indicating that humans could largely ignore the background image whereas the model could not. These results show that the human visual system is able to discriminate closed from open contours in a more robust fashion than transfer learning from the VGG network.

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43.373 **Border Ownership Assignment based on Dorsal and Horizontal Modulations** Paria Mehrani[1](paria.mehrani@gmail.com), John K. Tsotsos[1]; [1]Department of Electrical Engineering and Computer Science, York University

The face-vase illusion introduced by Rubin (Rubin, 1915) demonstrates how one can switch back and forth between two different interpretations by assigning borders to either side of contours in an image. Border ownership assignment is an important step in perception of forms. Zhou et al. (Zhou, Friedman, & von der Heydt, 2000) suggested that certain neurons in the visual cortex encode border ownership. They showed that the responses of these neurons not only depend on the local features present in their classical receptive fields, but also on the contextual information. Various models (Layton, Mingolla, & Yazdanbakhsh, 2012; Tschechne & Neumann, 2014) proposed employing feedback modulations for border ownership neurons as the neurons higher in the ventral stream have larger receptive fields and hence, can provide the required contextual information. Zhaoping (Zhaoping, 2005), however, suggested lateral connections could provide the required contextual information. The time course of border ownership neurons does not support feedback from higher layers in the ventral stream and that horizontal connections cannot be the only source of contextual information (Zhang & von der Heydt, 2010). In this study, we propose a model that provides the global information to border ownership neurons by incorporating modulatory signals from MT in the dorsal stream as well as horizontal connections. MT neurons are sensitive to spatiotemporal variations at coarser scales and have relatively large receptive fields. Moreover, they are computationally fast and fit well within the time course of border ownership computation (Schmolesky et al., 1998). Our simulation experiments show that our model border ownership neurons, similar to their biological counterparts, exhibit a difference of response to figure on either side of the border. Moreover, the difference in responses becomes smaller as the figure size increases and the responses are invariant to outlined and solid figures.

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43.374 **The event-related potential signature of adaptation to contours and textures** Damien Wright[1](damien.wright@stir.ac.uk), Jasna Martinovic[2], Elena Gheorghiu[1]; [1]Department of Psychology, University of Stirling, [2]School of Psychology, University of Aberdeen

Shape adaptation studies have suggested that contour-shape and texture-shape are processed by different mechanisms and surround-textures inhibit the processing of the shape of contours (Gheorghiu, Kingdom & Petkov, 2014). Here we examine the event-related potential (ERP) signature and time-course of neural processes involved in coding the shape of contours and textures before and after adaptation to assimilations and segregations of contours into or from surround textures. Stimuli were contours made of strings of Gabors oriented parallel to the path of the contour or textures made of a series of contours arranged in parallel. Texture-surround adaptors consisted of a central contour flanked by a surround made of parallel contours those Gabors orientations were either parallel or orthogonal to the path of the contours. Participants adapted to either pairs of sinusoidal-shaped textures or single contours that differed in shape frequency and the resulting shift in the apparent shape-frequencies of texture-test and contour-test pairs were measured together with the ERP responses from posterior brain regions. We found that (a) in the absence of adaptation, the negative amplitude of the ERP response peaked at around 150 ms for texture-tests and 225 ms for contour-tests. For post-adaptation: (b) contour-tests produced similar ERPs following adaptation to different types of adaptors from around 100 ms but with the ERP amplitude being more negative for single contour-adaptors than parallel and orthogonal texture-surrounds; (c) ERP responses to texture-tests were also dependent on the adaptor type, with amplitudes being larger when the adaptor was a contour than a texture. We conclude that the ERP responses to contour-tests and texture-tests are differentially modulated by contour and texture-adaptors. While ERP response to contour-tests is slightly modulated by both contours and surround-textures, the ERP response to texture-tests is only modulated by contour-adaptors.

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43.375 **The dynamics of eye movement behavior during a contour integration task** Carly J. Leonard[1](carly.leonard@ucdenver.edu), Caleb Dewey[1], Alexa Steed[1]; [1]Department of Psychology, University of Colorado Denver

Perceptual organization is critical for parsing incoming sensory information, and an important aspect of this challenge is to detect contours that represent edges of independent objects in the real world. During every day functioning, eye movements are frequently made to bring a subset of the visual field into the fovea, which offers improved spatial resolution. However, eye movements also change which specific neurons in the early visual system are activated. In this study, we investigate how this tradeoff is resolved by measuring eye movements during a contour integration task and how they impact performance. Participants performed a forced-choice discrimination task which required them to find an egg-shaped contour embedded in distractors and make a speeded response about its facing direction (left or right). The difficulty of this task was varied by jittering the orientations of the individual Gabor patches that made up the target contour. Orientations of the distractor Gabor patches were randomly chosen. To assess differential strategies, eye movement data were collected during this search task. The results show the expected response time pattern, such that greater contour jitter led to slower performance. Interestingly, dwell time before the initiation of the first saccade significantly correlated with subsequent behavior. Participants with longer dwell times made greater amplitude first saccades and required fewer eye movements to respond correctly. These results offer some perspective on how individuals may tradeoff between exploratory saccadic behavior in favor of extended perceptual processing which may benefit contour integration.

43.376 **Comparing filling-in of spatiotemporal patterns in the blind spot, under occlusion, and across artificial scotomata** Yulia Revina[1](yrevina@ntu.edu.sg), Gerrit Maus[1]; [1]Division of Psychology, School of Social Sciences, Nanyang Technological University

In the retinal blind spot, where the optic nerve exits the eye, visual input is always missing. Perceptual filling-in occurs at the blind spot and sometimes with artificial scotomata. Moving spatial patterns, but not static ones, lead to filling-in of spatiotemporal information in the blind spot (Maus & Whitney, 2016). However, it is unclear if the same occurs for artificial scotomata of the same size and eccentricity. Filling-in of artificial gaps improves with increasing eccentricity (De Weerd et al., 1998). Therefore, strong perceptual filling-in at the blind spot could be largely due to its peripheral location or because of a special filling-in mechanism. Here we compared perceptual filling-in of spatiotemporal patterns across the blind spot, occlusion and artificial scotomata (same size and eccentricity) in the fellow eye. In a psychophysical experiment, subjects viewed sinusoidal gratings at 5 spatial frequencies, 0.25-0.45 cycles/degree (cpd), and 5 gap conditions: control (no gap), blind spot, occlusion (an oval covered the center of the bar), and two deletion conditions (center of bar erased, with sharp or fuzzy edge). Participants responded whether bars from each condition or a standard control bar with no gaps at 0.3 cpd had "more stripes overall". We calculated the Points of Subjective Equality (PSEs) for each condition. Smaller PSEs mean that more stripes were perceived in the gap, indicating filling-in. We found that PSEs for the blind spot were lower than for other gaps, indicating better pattern filling-in across the blind spot. There was no difference in filling-in for occlusion vs deletion conditions. Comparing occlusion/deletion PSEs to the veridical amount of bars presented, we found that subjects somewhat overestimated the number of stripes (PSEs lower than predicted from accurate perception), suggesting some weak perceptual filling-in of occlusion and deletion. Additionally, the amount of filling-in (PSEs) was not related to the occluder size.

43.377 **Using artificial scotoma fading to explore antagonistic interactions in figure-ground perception.** Richard W Plummer[1](rwp13074@uga.edu), James M Brown[1], Jaeseon Song[1]; [1]Department of Psychology, University of Georgia

The perceptual fading experienced with an artificial scotoma can be viewed as a failure of figure-ground segregation making it a useful tool for investigating possible mechanisms and processes involved in figure-ground perception. Weisstein's model of figure-ground perception is based on antagonistic dorsal-M and ventral-P pathway interactions in the visual system where activity in the ventral-P stream encodes figure/foreground and activity in the dorsal-M stream encodes background (Weisstein, Maguire, & Brannon, 1992). Where a boundary separates two regions, which region is perceived as figure and which as ground is determined by the outcome of antagonism between dorsal-M and ventral-P signals both within each region and across the boundary between them. The region with the relatively stronger ventral-P "figure signal" is ultimately perceived as figure, the region with the relatively stronger dorsal-M "ground signal" is perceived as ground. From this perspective artificial scotoma fading occurs when the figure signal is overwhelmed by the ground signal. Therefore, anything strengthening the figure signal or weakening the ground signal should make the figure more resistant to fading. Our strategy used red (Exp's 1 & 2) and blue (Exp 2) light to reduce dorsal-M activity in both figure and ground regions based on research showing red light suppresses M activity and blue cones provide minimal input to M ganglion cells. Our figure was a 2°x 2° homogeneous square located 10° from fixation against a random-dot background. Time to fade (TTF) from stimulus onset until the figure completely disappeared was measured. Every possible combination of gray, green, red, and blue as figure and/or ground was tested. The results supported our predictions with TTF being greatest when red or blue light either (1) strengthened the figure signal by reducing M activity in figure, or (2) weakened the ground signal by reducing M activity in ground.

43.378 **Surface integration tendency determines relative depth order between two perceptually interpolated surfaces** Chao Han[1](han.1131@osu.edu), Teng Leng Ooi[1], Zijiang He[2]; [1]College of Optometry, Ohio State University, [2]Dept. Psychological and Brain Sciences, University of Louisville

We previously designed a self-splitting image comprising two intersecting and orthogonal gray bars (45-deg vs. 135-deg) with the same luminance (VSS 2017). When rendered in motion, the orthogonal bars were alternately seen in front (modal surface) and in back (amodal surface). This design paradigm allowed us to show that when the two bars have different widths, the wider bar was seen over a longer duration as the modal surface, in accordance with Petter's rule. One explanation for the rule is that the gap interval to interpolate is smaller for the wider bar, which endows it with a stronger tendency to integrate as a modal surface. To extend this explanation here, we examined the condition where both orthogonal bars were seen as amodal surfaces. This was achieved by using a red diamond-shaped occluder (0.8 x 0.8-deg) to cover the intersection of the orthogonal gray bars as they moved over one another. The bars had different widths (0.3 vs. 0.6-deg). We found that this arrangement resulted in observers seeing the two bars as amodal surfaces alternating in depth behind the diamond occluder. And importantly, the wider bar enjoyed a higher predominance of being seen on top of the thinner bar. Thus, our finding extends Petter's rule to overlapping amodal surfaces. We then modified the display by making the two bars the same width (0.3-deg) but with different contrast values (10% vs. 31.6%). We found that this caused the amodal bar with the higher contrast to be seen on top more frequently. This suggests high contrast increases the tendency for surface integration and causes it to seen on top. Altogether, our results support the general notion that surface integration tendency is an important factor in determining perceived depth order between perceptually interpolated surfaces, no matter whether they are modal or amodal surfaces.

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43.379 **Motion tuning and element lifetime properties of symmetry detection mechanisms** Rebecca J Sharman[1](rebecca.sharman@stir.ac.uk), Elena Gheorghiu[1]; [1]Department of Psychology, University of Stirling

Mirror symmetry is believed to be encoded by specialised visual mechanisms. Recent evidence suggests that symmetrical motion-direction does not contribute to symmetry perception, but limiting the lifetime of pattern elements improves performance (Sharman & Gheorghiu, 2017). Here we examine whether symmetry detection mechanisms are selective for speed and lifetime duration of symmetrical pattern elements. Stimuli were dynamic dot patterns containing different amounts of positional-symmetry about the vertical axis. Symmetric patterns contained both position and motion-direction symmetry with matched-pairs moving in symmetrical directions, but with different pairs having randomly allocated directions. Noise dots moved in the same directions as signal dots, but did not have positional symmetry. We used stimuli in which symmetry signal and noise dots drifted at either the same or different speeds. We manipulated the amount of positional symmetry by varying the proportion of symmetrical dots and measured symmetry detection thresholds using a 2IFC procedure. Foil stimuli were noise patterns containing the same speed distribution as the symmetric stimuli. These symmetry detection thresholds were compared with those obtained with (i) static patterns and (ii) dynamic-flicker patterns in which the symmetry signal and noise dots had either the same or different lifetime durations and were relocated without local motion. We found that (a) symmetry detection thresholds were lower for moving and dynamic-flicker patterns than for static patterns in all conditions; (b) thresholds were higher when the symmetry signal and noise dots had the same speed and decreased gradually with increasing speed differences between symmetry signal and noise dots; (c) thresholds for dynamic-flicker patterns increased gradually with the ratio of symmetry-to-noise lifetime duration. We conclude that symmetry detection mechanisms are tuned to the speed of symmetrical motion and this is not explained by increasing the number of symmetrical element-locations as elements move from one location to the next.

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43.380 **Visual cortex is sensitive to order-disorder phase transition** Mikhail Katkov[1](mikhail.katkov@gmail.com), Francesca Strappini [1,2], Tomer Livne[1], Sabrina Pitzalis[3,4], Dov Sagi[1], Rafi Malach[1]; [1]Department of Neurobiology, Weizmann Institute of Science, [2]Istituto Neurologico Mediterraneo Neuromed, Pozzilli (IS), Italy, [3]Department of Education in Sport and Human Movement, University of Rome ''Foro Italico,'' Rome, Italy , [4]Neuropsychology Center, Santa Lucia Foundation, Rome, Italy

Initial stages of visual processing are well characterized in terms of band-limited oriented receptive filters. However, brain mechanisms underlying the integration of their outputs are much less understood. In the domain of texture perception, two types of mechanisms have been suggested: (A) first-order statistics and (B) autocorrelation function. In texture perception, considering local symmetry as a statistical property, we can employ the order parameter used in physics to analyze transitions between order and disorder. When the thermodynamic temperature (T) decreases monotonically, the order parameter changes monotonically from zero for disordered systems to one for symmetric systems. Recently, we have synthesized images corresponding to different T's and showed that human observers are sensitive to phase transition. Their sensitivity function is well approximated by an observer based on the order parameter. Here, we investigated the neural correlates of order-disorder perception using functional imaging combined with a phase-encoded paradigm. We hypothesized that BOLD response would depend monotonically on T if first-order statistics are involved. Conversely, the BOLD response would be larger for images around phase transition than for symmetric and disordered images if autocorrelation is involved, since correlations of all lengths are present only in these images. We presented the stimuli in 4 consecutive 16 s blocks: 1) disordered images, 2) images with continuous change of order parameter from disordered to symmetric, 3) symmetric images, 4) images with continuous change of the order parameter from symmetric to disordered. We found that the BOLD response in early visual areas as well as in lateral occipital complex (LOC) was highest for images close to the phase transition, thus supporting the autocorrelation hypothesis and rejecting first-order statistics as an underlying mechanism. These results may partially account for the weak activation of the LOC to both highly ordered and highly disordered textures compared to object shapes.

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Visual Search: Memory

Monday, May 21, 8:30 am - 12:30 pm, Pavilion

43.401 **An individual difference examination of the relationship between spatial working memory abilities and contextual cueing.** Kirk Ballew[1](kballew2@illinois.edu), Alejandro Lleras[1], Simona Buetti[1]; [1]University of Illinois at Urbana-Champaign

Contextual cueing is the facilitation of visual search via exposure to repeated displays in which distractor locations are predictive of the target location. Reaction times decrease more over time for repeated displays than for displays in which distractor locations change across blocks (Chun & Jiang, 1998). Recently, this effect was shown to be dependent upon visuospatial working memory (VWM). When VWM was loaded up by tasks run concurrently with the contextual cueing paradigm, the typical benefit of repeated displays was reduced or eliminated (Manginelli, Geringswald, & Pollman, 2012; Travis, Mattingley, & Dux, 2013). We hypothesized that, if VWM underlies the contextual cueing effect, then individual differences in VWM will determine the magnitude of the effect. Toward that end, we developed four tasks to measure VWM and compared individual differences on these measures to performance on the standard contextual cueing task. Two of the tasks were based on the Corsi Blocks task (Alloway & Cockcroft, 2014). In the serial version, participants were asked to remember, and subsequently identify in order, sets of spatial locations presented serially within a grid. Set size increased across trials. The simultaneous version was identical to the serial task, except that the locations appeared simultaneously and response order did not matter. We also used two change detection tasks. In the first task, participants were asked to detect changes between pairs of displays containing seventeen spatial locations arrayed within a grid. In the second task, participants were asked to detect changes between pairs of displays containing four dots arrayed along an invisible circle. Finally, we also included a measure of general visual ability (developed by Richler, Wilmer & Gauthier, 2017). The findings are discussed in terms of the different underlying memory constructs that contribute to learning the subtle display configurations, and produce the Contextual Cueing benefit.

43.402 **Target Category Repetition Reduces the Reliance on Visual Working Memory as Measured by Contralateral Delay Activity** Ashley M Ercolino[1](ashley.ercolino@knights.ucf.edu), Joseph Schmidt[1]; [1]University of Central Florida

We often consecutively search for the same target category; airport security screeners search for weapons in multiple bags and when driving in traffic we constantly monitor for brake lights and pedestrians. Identical target repetition results in faster search, less target information stored in visual working memory (VWM) as indicated by contralateral-delay-activity (CDA), and an increased reliance on long-term-memory (LTM) as indicated by the frontal P170 (Woodman, Carlisle, Reinhart, 2013). Moreover, when a difficult search is expected, more target details are maintained in VWM as indicated by increased CDA; importantly, participants who maintain additional target details were least affected by the increased search difficulty (Schmidt & Zelinsky, 2017). This suggests that target representations affect search performance and change over-time. We asked if consecutive target category repetition would result in a reduced reliance on VWM (as indicated by reduced CDA) and an increased reliance on LTM (as indicated by a decrease in the frontal P170), in addition to a search benefit. Participants searched for a fish, flower, butterfly, car, or teddy bear target for five consecutive trials before the target category changed; eye movements and EEG were recorded throughout. Participants were cued to attend to one of the bilaterally presented stimuli which designated the search target (200ms). This was followed by a 1000ms ISI in which CDA was recorded. In the search display, participants localized search targets, which were 100% present and appeared along with five distractors from non-target categories. Despite target category repetition producing no observable change in behavioral and eye movement measures of search accuracy, search guidance, or target verification time, and a lack of an observable frontal P170; CDA significantly decreased ($p < .001$) with target category repetition. This suggests that target category repeats results in less reliance on VWM, consistent with the use of a more categorical target representation.

43.403 **Relevance Effects in Repeated Visual Search** Sebastian A. Bauch[1](sebastian.bauch@uni-graz.at), Christof Körner[1], Iain D. Gilchrist[2], Margit Höfler[1]; [1]Institute of Psychology, University of Graz, [2]School of Experimental Psychology, University of Bristol

In repeated visual search, little is known about whether foreknowledge of a target-defining feature in an upcoming search affects a current search already. Therefore, we investigated in three experiments, to what extent oculomotor behavior during two consecutive searches is affected by the knowledge of the target color of the second search. Participants searched a display consisting of pink and blue letters twice. They were informed that, in Search 1, the target could be pink or blue, whereas in Search 2, the target color was constant. In order to measure whether foreknowledge of the target color affects both searches, we analyzed saccadic latencies to a probe presented on a relevant or irrelevant item during Search 1 and at the beginning of Search 2 (Experiment 3 only). Participants were requested to saccade to this probe as fast as possible and then to continue the search. Furthermore, we analyzed saccadic latencies and number of fixations to (unprobed) relevant and irrelevant items. Across experiments, we found, in Search 1, shorter saccadic latencies to unprobed relevant compared to irrelevant items but no differences in latencies to the probed (relevant or irrelevant) item. Also, there was no difference in the number of fixations to relevant and irrelevant items. In contrast, in Search 2, we found shorter saccadic latencies to both unprobed and probed relevant compared to irrelevant to items. Furthermore, participants inspected more relevant than irrelevant items. Taken together, oculomotor programming in repeated search is, at least to some extent, affected by a prospective target feature and can adapt immediately once a change in relevance occurs.

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43.404 **How information in working memory affects attentional control in older and young adults?** Jian Guo[1](guo.jian.77w@st.kyoto-u.ac.jp), Takatsune Kumada[1]; [1]Department of Intelligence Science and Technology, Graduate School of Informatics, Kyoto University

Working memory is used in storage and manipulation of a limited amount of information for present or coming cognitive tasks. Visual attention is used to select relevant information and ignore irrelevant one for a present task. Recent studies have shown interactions between selective attention and visual working memory even when memory items are irrelevant for visual search. In addition, studies of cognitive aging have demonstrated that functions of attention and those of working memory decline with age. However, so far, no study has examined the effect of normal aging on working memory-guided attentional control. In this study, the effect of aging on working memory-guided attentional control was examined by using a typical experimental method which required participants to remember certain items and then search for a target object among distractors. In some trials, one of the distractors was replaced by an item remembered before the search or by an item that was not remembered. The results show that for older adults, working memory items did not capture attention in visual search tasks compared to young adults. In addition, a simplified experiment provided evidence for WM guided attentional control in older adults when interval (in between the memory item display and visual search display) is short. The mechanism behind these findings was discussed and working memory models were modified to indicate the effect of aging on working memory-guided attentional control.

43.405 **Enhanced distractor memory following difficult search: The role of attention allocation in incidental encoding** Juan D Guevara Pinto[1](jgueva3@lsu.edu), Megan H Papesh[1], Stephen D Goldinger[2], Michael C Hout[3]; [1]Louisiana State University, [2]Arizona State Universtiy, [3]New Mexico State University

There exists a paradoxical finding in visual search: When observers search for multiple targets, relative to single targets, they are slower and less accurate, yet have better incidental memory for non-target items encountered throughout the task (Hout & Goldinger, 2010). One explanation for these effects may be that observers titrate their attention allocation based on the subjective difficulty suggested by the search cue. When observers expect a difficult (e.g., multiple-target) search, they may dedicate additional resources to the primary task by increasing visual scrutiny of each object, which enhances incidental distractor encoding. Across two experiments, we replicated and extended prior work by examining the mnemonic and attentional consequences of easy versus difficult Rapid Serial Visual Presentation (RSVP) search cues. In Experiment 1, observers monitored RSVP search streams following relatively difficult cues (words) or easier cues (pictures). Although primary task performance was better with pictures cues, observers exhibited better incidental recognition for distractors following word cues. In Experiment 2, we examined whether easy and difficult search cues lead to different levels attention allocation, which could underlie differences in subsequent distractor recognition. In 20% of search trials, a peripheral shape appeared at various degrees of visual angle off the central RSVP stream. Observers' task was to identify the peripheral distractor without sacrificing primary task accuracy. Replicating Experiment 1, search performance was better following picture cues. More importantly, observers were also more likely to accurately identify the peripheral distractor on pictured-cued trials, suggesting that picture and word cues demand different levels of attentional engagement. Specifically, observers seem to focus additional attentional resources on the central RSVP stream when search will be relatively difficult, causing them to miss peripheral distractors, but potentially remember central distractors.

43.406 **Cued by the bzzzzzzzz?! The influence of object sounds on visual search and memory performance** Caroline D Seidel[1](caroline.seidel@stud.uni-frankfurt.de), Dejan Draschkow[1], Melissa L.-H. Võ[1]; [1]Department of Psychology, Scene Grammar Lab, Goethe University Frankfurt

Auditory processing is an important component of natural experiences and might bias visual search tasks. Prior studies demonstrated that a non-spatial, target synchronous sound speeds up visual search. Even when we dissolve the synchronicity between the visual and auditory information, a target characteristic sound facilitates several components of visual search performance while searching artificial displays. In two experiments, we tested the influence of sound cues on visual search and memory performance in real-world scenes. In Experiment 1 (N=16), participants had to search for target objects in 72 colored images of scenes. Before starting the search, the scene was briefly presented, followed by a visual cue. We manipulated the subsequent auditory cue by presenting either a characteristic sound congruent with the target or an unrecognizable version (scrambled) of the same sound. The target object in the scene could be located in syntactically consistent (e.g., an electrical toothbrush next to the sink) or inconsistent (e.g., the same toothbrush stuck in the towel rack) locations. After completing the visual search task, participants' identity and location memory was tested. In Experiment 2 (N=15), the participants had to perform the same search task, with the difference being that distractor sounds instead of scrambled sounds were presented. For distractor sounds we used the sound of objects located in the same scene as the target. In both experiments, objects located consistently were found faster than inconsistently placed ones. In contrast to previous studies, non-spatially informative sounds neither significantly influenced visual search nor memory performance in scenes. This effect could be attributed to an overall difference between scene and display search (e.g.,

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use of scene-syntactic guidance), semantic similarity of the sounds or the low task relevance of the sound.The bzzzz might guide your tooth-brushing, but your scene search not so much.

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43.407 **How NOT to cure the incidental finding problem in radiology: Experience with "mixed hybrid" visual and memory search** Makaela S. Nartker[1](mnartker@bwh.harvard.edu), Jeremy M. Wolfe[1,2]; [1]Brigham & Women's Hospital, [2]Harvard Medical School

A radiologist searching for something specific (e.g. lung cancer) is also responsible for reporting any "incidental findings" (e.g. pneumonia) that could be clinically significant. Incidental findings are frequently missed, posing a problem for radiologists, their patients, and their lawyers. In 2017, Wolfe et al. proposed 'mixed hybrid search' as a model system for incidental findings. Non-expert observers memorized a set of three specific, photorealistic object targets (analogous to the primary goal of search). They also memorized three target categories, such as "animals" or "hats" (analogous to the less well-specified, incidental findings). They then searched displays for any instance of any of the specific or categorical targets held in memory. Since incidental findings are relatively rare, categorical targets were presented on 20% of target-present trials. Observers missed 5% of specific targets but fully 38% of categorical targets, mirroring the high error rate for incidental findings. We tested two strategies intended to reduce the number of missed categorical targets. In Experiment 1, we reminded observers about the categorical targets via non-search trials in which categorical targets were clearly marked. In Experiment 2, we forced observers to respond twice on each trial: Once to confirm the presence or absence of specific targets, and once to confirm the presence or absence of categorical targets. Both of these interventions failed. Even when observers had to explicitly state that there were no categorical targets, categorical miss error rates remained over 30%. Like the real incidental finding problem, these are stubborn errors. It is possible that a more rigorous checklist procedure might help, but radiologists will not thank us if we vastly increase the time per case. Wolfe, J. M., Alaoui-Soce, A., & Schill, H. (2017). Cognitive Research: Principles and Implications (CRPI), 2, #35. doi:10.1186/s41235-017-0072-5.

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Visual Memory: Contents

Monday, May 21, 8:30 am - 12:30 pm, Pavilion

43.408 **Binding of Color and Shape in Visual Working Memory Survives Dynamic Object Tracking** Jun Saiki[1](saiki.jun.8e@kyoto-u.ac.jp); [1]Graduate School of Human and Environmental Studies, Kyoto University

The nature of feature-bound object representations in visual working memory (VWM) remains unclear. Many studies claim that compared with single features, feature binding representations are held by a resource-limited system, and are fragile. Using an experimental paradigm combining redundancy gain and object reviewing tasks (Saiki, 2016), the current study showed that color-shape binding representations for multiple objects are maintained in a robust fashion in VWM. A set of features was presented in a two-object memory display, followed by a linking display in which placeholders either moved or stayed. Then a single object probe was presented, and participants judged if it contained any features of the memory display, regardless of object correspondence. The index of feature co-activation measures the advantage of color-shape conjunction relative to single features in memory matching. Object specific preview benefit (OSPB) index reflects the advantage of object correspondence in access to a task relevant memory representation, either conjunction or single feature whichever matches first. The cost of object motion on these indices can test two hypotheses on the nature of the binding memory. If objects' motion destroys fragile binding memory, the feature co-activation should be reduced, while OSPB remains intact because single feature memory is still accessible. If the binding memory is robust and the cost of motion reflects the tracking failure of object VWM, OSPB should be impaired, while feature co-activation remains intact. A series of experiments revealed strong feature co-activation and OSPB when objects are stationary, replicating previous work. Critically, feature co-activation was retained regardless of object motion, whereas OSPB was substantially reduced when objects moved, supporting the hypothesis of robust color-shape binding in VWM. The cost of object motion in the memory matching performance likely reflects the tracking failure of object VWM, and feature binding memory survives dynamic object tracking.

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43.409 **Examining the Impact of Item-Distractor Similarity Using a Validated Circular Shape Space** Aedan Y Li[1](aedanyue.li@mail.utoronto.ca), Celia O Fidalgo[1], Jackson Liang[1], Andy C H Lee[1,2], Morgan D Barense[1,2]; [1]Department of Psychology, University of Toronto, [2]Rotman Research Institute, Baycrest

Previous work suggests that the similarity of distracting information can differentially alter how visual representations are forgotten. Though these effects have been shown for color memory, it is unclear if they reflect more general principles and will extend to other object features such as shape. In Experiment 1, we describe the creation of the Validated Circular Shape Space (VCS space), a "Shape Wheel" whereby 2D line drawings were morphed together to create an array of 360 shapes, corresponding to 360 degrees on a circle. We iteratively developed VCS space by designing prototype shapes, morphing the shapes to create a circular space, collecting pairwise similarity ratings, constructing subjective space using multidimensional scaling (MDS), then redesigning the prototype shapes that were problematic. This procedure required seven validation steps, with the final validation step ensuring that angular distance on VCS space was a proxy for subjective similarity. In Experiment 2, we then used VCS space to assess how shape memory was impacted by distracting information that varied in subjective similarity relative to a study shape. A mixture model was used to operationalize memory as two separate components: the probability that study items were successfully remembered, defined as accuracy, and the level of detail, defined as precision. Relative to a baseline scrambled-line condition, we found that subjectively dissimilar distractors decreased accuracy but not precision, while subjectively similar distractors decreased precision but not accuracy. These findings extend previous literature by demonstrating the nature of visual interference differentially impacted shape memory. Subjectively dissimilar interference erased memory, whereas subjectively similar interference blurred representations. As these effects were consistent across studies, we suggest they provide converging evidence for a set of general principles regarding how interference impacts visual representations and the features therein.

43.410 **Similarity-based clusters are the representational units of visual working memory** Gaeun Son[1](sohngaeun@gmail.com), Byung-Il Oh[2], Min-Suk Kang[2], Sang Chul Chong[1,3]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Sungkyunkwan University, [3]Department of Psychology, Yonsei University

Clustering is an efficient strategy to represent redundant information with limited memory resources. If apples have similar shapes and colors in an orchard scene, the visual system may encode a cluster of apples rather than each different apple's individual shape and color. The current study investigated the impact of clustering on representational quality of visual working memory (VWM). We hypothesized that similar items are organized into a cluster, and their recall precision becomes higher with fewer clusters. Across four experiments, we manipulated the orientation similarity of several bars so that they formed a different number of clusters. Participants remembered bar orientations and later estimated the orientation(s) of cued bars. Based on these estimations, we measured recall bias to confirm that similarly oriented bars formed a cluster, and measured recall precision to test whether the recall quality improved with fewer clusters. Specifically, in Experiments 1 and 2, five bars formed one, two, or three clusters. In Experiment 3, five bars formed two clusters, or three bars each formed their own clusters. Consistent with the prediction, similar orientations were recalled with a bias toward their mean orientation, indicating that similar items formed a cluster. Also, recall precision of each item was higher with fewer clusters, regardless of the number of individual items. In Experiment 4, we parametrically manipulated the similarity between cluster means and measured response correlation in addition to recall bias and precision. We found that response correlation was not influenced by the similarity between the cluster means. This result indicates that it is the number of clusters itself that has a critical role for VWM quality, rather than the similarity between clusters. Taken together, we suggest that clusters formed by similar items impact VWM representation and its quality, acting as representational units of VWM.

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43.411 **The time course of selective encoding and maintenance of task-relevant object features in working memory.** Andrea Bocincova[1](andrea.bocincova@ndsu.edu), Jeffrey S. Johnson[1]; [1]Department of Psychology, Center for Visual and Cognitive Neuroscience, North Dakota State University

Studies of object-based attention have shown that when one feature of a multi-feature object is selected, attention tends to spread to other, task-irrelevant features (Ernst et al., 2013). Other evidence suggests that access to WM can be restricted to only relevant features (Serences et al., 2009; Woodman & Vogel, 2008). Another possibility is that all of an object's features are initially encoded, but irrelevant features are removed from WM over time (Logie et al., 2010). We used MVPA trained on time-frequency decomposed EEG data to examine the temporal evolution of neural representations reflecting the encoding and storage of task-relevant and irrelevant features in WM. In different blocks, participants remembered the orientation, color or both orientation and color of a colored, oriented grating. The color and orientation of the grating was randomly drawn from two distinct feature bins on each trial. A trained support vector machine (SVM) classifier was successful at significantly classifying the task-relevant feature dimension (color, orientation, both) across the whole trial interval including the pre-stimulus interval, although classifier accuracy was higher during the encoding and delay intervals. To examine trial-specific activity reflecting storage of the object's features, the classifier was trained to classify what bin the task-relevant and task-irrelevant feature came from. Interestingly, for orientation, the classifier produced reliably above-chance classification across the delay for the task-relevant feature but not the task-irrelevant feature. Importantly, orientation could be accurately classified on trials for which both orientation and color were remembered. Moreover, classifier evidence was much higher for the correct bin when orientation was task-relevant compared to task-irrelevant during encoding. Above-chance classification for color was only present during the initial 500 ms across all conditions. Our results suggest that both task-relevant and task-irrelevant features are initially encoded, but only task-relevant features continue to be actively represented across the delay period.

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43.412 **Objects are represented as integrated items in visual memory** Dana Assaf[1](dana.assaf.01@gmail.com), Halely Balaban[1,2], Roy Luria[1,2]; [1]The School of psychological Science, Tel-Aviv University, Israel, [2]Sagol School of Neuroscience, Tel-Aviv University, Israel

This study investigated whether objects are represented as individual features or as integrated objects in visual memory. Participants were presented with pictures of real-world objects and were later tested for their memory. There were four options for each object, created by combining two different exemplars (e.g., two different bottles), and two different variations of another feature. For different objects, the other feature was either state (e.g., open or closed), orientation (e.g., straight or rotated) or material (e.g., glass or metal). Participants were asked to choose the object they saw in the first part. Three days after the first session, participants returned for a second memory test phase. As expected, we observed a decrease in the number of remembered items in the long-term test as compared to the immediate memory test. The objects-based theory states that we represent objects in memory as integrated objects and not as individual features. Therefore, the object-based model predicts that the number of forgotten items between the short and long term test should match the increase in the guessing rate, because the object should be forgotten completely. Furthermore, this model predicts that there would be no increase in the partially-correct answers (i.e., objects for which only one feature was remembered) between the short and long-term test. The results verified these predictions: when comparing the short and long-term test, the decrease in the number of fully correct answers was equivalent to the increase in guessing rate ($t(19)=0.64$, $p=0.53$). In addition, there was no significant difference in the partially-correct answers ($t(19)=0.55$, $p=0.58$) comparing the short and long-term test. Several following experiments replicated these results with a shortened presentation time and with an explicit memory study phase. These results support the object-based theory that claims memory hold integrated objects instead of represented separated features.

43.413 **Knowledge about real-world objects influences visual working memory capacity** Ariel Starr[1](arielstarr@berkeley.edu), Mahesh Srinivasan[1], Silvia A Bunge[1]; [1]UC Berkeley

How does our knowledge about the world influence what we remember? Are we better able to remember items we are familiar with? Across four experiments, we examined how visual working memory capacity varies as a function of object familiarity in both adults (Experiments 1-3) and children (Experiment 4). Experiment 1 was a replication of Brady et al. (2016), in which we compared visual working memory capacity in adults for arrays of five colored squares or real-world objects with variable encoding times. Memory capacity for both colors and objects increased between 300 and 1000ms, but memory for colors leveled off while memory capacity for real-world objects continued to increase with 2000ms of encoding time. In the following experiments, we compared memory capacity for familiar real-world objects (selected based on picture labeling data from children aged 4-6 years; Robertson & Kohler, 2007) versus unfamiliar real-world objects (pictures of three-dimensional uncommon and novel objects). In Experiment 2, we used the same paradigm as Experiment 1 and found that while memory capacity increased at each encoding duration for both types of stimuli, memory was better overall for familiar objects compared to unfamiliar objects. In Experiment 3, we controlled for the possibility that better memory for familiar objects stems from verbal labeling by having participants perform a simultaneous verbal task. Once again, we found that memory capacity was significantly higher for familiar compared to unfamiliar objects. In Experiment 4, we compared memory capacity in children aged 5-7 years for arrays of four familiar or unfamiliar objects with 2000ms of encoding time. Similar to adults, we found a trend towards increased capacity for familiar compared to unfamiliar objects. Together, our data suggest that semantic knowledge influences the capacity of working memory, challenging traditional views of working memory capacity and development.

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43.414 **The Number of Representations within the Focus of Attention in Visual Working Memory** Hyung-Bum Park[1](hpark053@ucr.edu), Weiwei Zhang[1]; [1]Department of Psychology, University of California, Riverside

Representations in working memory (WM) can have different levels of activation for representations within and beyond the focus of attention (FoA), according to some recent state models of WM. It is, however, still unclear whether the internal FoA in WM can maintain only a single representation at a time or multiple representations concurrently. To test the two competing hypotheses, we manipulated the number of retro-cues in a delayed estimation task in which participants were required to memorize three briefly presented colors over a short delay interval and then reproduced one of the remembered colors on a continuous colorwheel. The errors in these short-term recall responses were fit with Zhang & Luck (2008) mixture model, producing estimates of the probability of remembering and mnemonic precision of retained memory representations. In the middle of the delay interval, one, two, or three items in WM were cued simultaneously. The probability of remembering decreased significantly from the one-cue condition to the two-cue condition, but remained highly comparable between the 2-cue and 3-cue conditions, indicating a bottleneck for the FoA. In contrast, as the number of retro-cues increased, mnemonic precision decreased, reflecting the decrease in the amount of attentional resources that each cued item received. Similar pattern also manifested to reaction time (RT) based on ex-Gaussian model fits of RT distributions. Taken together, the results provide strong support for a highly-limited capacity for the FoA within WM.

43.415 **Capacity for Visual Features in Mental Rotation is Persistently Low** Nicole L Jardine[1](nicole.jardine@northwestern.edu), Steven L Franconeri[1]; [1]Psychology, Northwestern University

Monday AM

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It has been proposed that visual working memory (VWM) is better for real-world objects than for sparse laboratory objects (Brady, Konkle, Oliva, & Alvarez, 2009). One of many gaps between "sparse" and "real world" objects is that real-world objects can have repeating structures that observers might use to encode object features and predict how it will appear after rotation. VWM capacity for mental rotation of sparse objects comprised of multiple oriented bars drops to near 1 (Xu & Franconeri, 2015), but it is possible that adding additional object structure may improve VWM for mentally rotated object features. Here, observers saw novel highly structured objects comprised of 6 connected cubes, with two cubes forming the "head and body" of the object and four "feet". The object then disappeared and underwent a cued rotation in depth (blocked design) that was small or large. The rotated object appeared with the same organization or with swapped colors of two of the cubes. Task performance relies on accurate binding, updating, and comparison of object features. Observers successfully performed large object rotations with no swaps, and were mildly impaired when a swap involved the top two cubes, even though all large rotations involved large changes in the retinal positions of cube colors. But when swaps occurred between two feet, accuracy at these same large rotations was devastated. This particular sensitivity to upper objects and lack of sensitivity (or failure to update) lower objects is consistent with prior findings on low capacity for rotation of simpler features, and suggests that structure alone is insufficient to produce VWM capacity benefits. Further work will continue to map the space between "sparse" and "real-world" objects, and to elucidate what characteristics, if any, promote improved VWM capacity for real-world objects.

Acknowledgement: NSF DRL 1661264

43.416 **The psychophysical properties of working memory and mental rotation reveal different processes** Joel Robitaille[1], Stephen M. Emrich[1]; [1]Department of Psychology, Brock University

Despite the fact that the influential Working Memory (WM) model proposed by Baddeley and Hitch (1974) included the manipulation of information as a fundamental aspect of this cognitive ability, how individuals manipulate mental representations remains an underexplored area in vision science. Moreover, though the psychophysical properties of WM are well established for simple stimuli (eg. lines, colors), less is known about WM for more complex stimuli. In contrast, the mental imagery literature has commonly used 3D stimuli to investigate the manipulation of mental representations, however less is known about the psychophysical properties of mental imagery abilities. In this study, we compared the psychophysical properties of the storage and manipulation of lines and complex 3D Tetris shapes. In Experiment 1, participants were required to remember the orientation of both types of stimuli in a classic WM delayed-recall paradigm that varied memory load. Overall recall error was worse for complex 3D shapes than for lines, with increased WM load having a greater effect on precision for the complex shapes. Experiment 2 investigated the effect of manipulating the memory of a single stimulus through mental rotation. During the delay of a single item delayed-response task, participants were cued to either report the stimulus as it was presented (WM condition) or to mentally rotate the stimuli (60° or 120°). The results reveal that for both stimuli, recall error increased as a function of rotation magnitude, paralleling the effects of load in Experiment 1. Interestingly, in both experiments, WM precision as measured by raw error was uncorrelated between stimulus type, suggesting the ability to represent visual information in WM may be stimulus dependent. Moreover, the precision of WM showed no signs of correlation with mental rotation precision, suggesting that these two visual cognitive abilities may be independent, contrary to some theoretical models.

Acknowledgement: NSERC

43.417 **Comparing memory based on visual recall, visual recognition, and verbal recall** Elizabeth H. Hall[1](elizabeth.hall@nih.gov), Wilma A. Bainbridge[1], Chris I. Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health

Recent work on visual recognition memory has characterized its high capacity and detail. However, visual recall has received less attention in spite of evidence for a neural dissociation from visual recognition, and is often assessed with verbal paradigms, which may miss key information about the visual content of memories. Here, we assess visual recall through a purely visual task (drawing) and compare it with visual recognition memory and verbal recall. Participants (N=30) studied 30 real-world scene images from distinct categories (10s each), and after a 11-minute distractor task, completed both a free recall drawing task and an old/new recognition task with same-category foil images. As previous work has identified memorability as a consistent predictive image property for recognition success (Bainbridge et al., 2013), stimuli were counterbalanced for memorability across participants (highly memorable versus highly forgettable). A separate group (N=15) completed a verbal version of the free recall experiment, studying category labels only. On average, participants recognized 27.2 images in the recognition task, remembered 16.7 items during verbal recall, and remembered 12.1 images (out of 30) during visual recall. However, they visually recalled a further 5.7 images when cued with a salient object. While both verbal and visual recall showed a primacy effect, this effect was stronger for verbal recall. There were no significant correlations at either the subject level or stimulus level for which items were visually recognized versus recalled. Importantly, while highly memorable images were better recognized, they were not more likely to be recalled than forgettable images, supporting a dissociation between recognition and recall memory. All together, these results provide evidence for visual recall as a distinct process separate from visual recognition and verbal recall.

43.418 **Do occluding boundaries extend in visual memory?** Carrick C Williams[1](cawilliams@csusm.edu), Kelly Edwards[1,2]; [1]California State University San Marcos, [2]University of Oregon

When remembering occluded objects, it is possible visual memory fills in missing information, representing more of the object than was actually presented. This amodal completion would be similar to a boundary extension bias where scenes are remembered from a greater distance with extensions of the edges and completion of objects on the edge. If boundary extension operates in visual memory for occluded objects, we should demonstrate a bias to remember objects as less occluded than presented. Participants were shown images of 120 objects that were occluded 40% to 60% (randomly intermixed) with the object occluded on a single side or in alternating visible and occluded stripes. After the study phase, participants were given a five-alternative memory test in which they had to select the previously seen level of occlusion (40-60%). Boundary extension would be evident if memory errors were skewed toward selecting foils with less occlusion than was presented. We restricted the analysis to the 45%, 50%, and 55% occluded conditions because they had memory foils to either side of the correct answer. A boundary bias score was created where a correct answer was given a 0, boundary extension was given a -1, and boundary constriction (remembering a less visible object) was given a 1. Overall, we failed to find consistent boundary extension bias. For the 50% occlusion condition, the boundary bias score was not different than 0. For the 45% occlusion condition, we found a boundary constriction bias, but in the 55% occlusion condition, we found a boundary extension bias. In other words, participants appeared biased to guessing more toward the middle level of occlusion rather than remembering the object as more visible. These results indicate that, although boundary extension may be operating in scene memory, the same bias is not found when remembering occluded objects.

43.420 **Representational dynamics of number processing in symbolic and non-symbolic formats** Daniel Janini[1,2](janinidp@gmail.com), Brett B Bankson[1,3], Chris I Baker[1]; [1]Section on Learning and Plasticity, Laboratory of Brain and Cognition, National Institute of Mental Health, Bethesda, MD, USA, [2]Psychology Department, Vision Sciences Laboratory, Harvard University, Cambridge, MA, [3]Psychology Department, Laboratory of Cognitive Neurodynamics, University of Pittsburgh, Pittsburgh, PA

The human brain can rapidly form number representations from a variety of visual formats including digits, number words, and dot displays. While an extensive literature has investigated where these symbolic and non-symbolic number representations are formed in the brain, less is known about the temporal aspects of this process. Here, we explored the emergence of number representations by applying multivariate pattern analyses to MEG data. Participants (n = 22) encoded the magnitude of visually presented numbers across three different formats (digits, words, and dot displays). First, we investigated how quickly the brain forms individual number representations from visual input, and if this differs between formats of presentation. We used a support vector machine (SVM) to classify number within each format at each time point. The SVM results revealed peak decoding at 110-120ms following stimulus presentation within each of the three formats. Next, we assessed whether number magnitude and visual shape models could explain the variance in neural response to different stimuli. Representational similarity analyses (RSA) were used to compare number magnitude and visual shape models to the neural responses. RSA yielded the highest correlations to the number magnitude model at around the same time point as peak decoding accuracy - 120ms for digits, 135ms for words, and 120ms for dot displays. With regard to the shape model, the highest correlations were found at different time points depending on the format - 170ms for digits, 70ms for words, and 120ms for dot displays. Thus, individual number representations are formed quickly by the brain for both symbolic and non-symbolic formats of presentation. These representations emerge concurrently with magnitude information, while shape information appears to drive the MEG signal in a more format-specific manner.

Visual Memory: Encoding and retrieval

Monday, May 21, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.421 **Quantifying sensory noise in serial dependence experiments with a two alternative forced choice (2AFC) paradigm** Fraser R Aitken[1](fa28@st-andrews.ac.uk), Justin M Ales[2]; [1]University of St Andrews, [2]University of St Andrews

Serial dependence is a phenomenon in which people's perceptions of current stimuli values depend on previously seen stimuli. However, it is still poorly understood which aspects of a stimuli affect the amount of serial dependence observed. One theory is the visual system weights stimulus values adaptively depending on sensory noise. When stimuli are less noisy more weight is attached to new values and under more noisy conditions more weight is attached to past values. One problem is that previous studies have not quantified the amount of sensory noise present in stimuli and used a method of adjustment procedure that contains response noise. Here we measure sensory noise. We did this by using a two-alternative forced choice paradigm (2AFC). Participants viewed a Gabor stimuli presented at a random orientation. Next a second Gabor was presented at 7 different angles ranging 15° either clockwise or anticlockwise from the initial orientation. Sensory noise was manipulated by presenting the Gabors in two contrast conditions 5% contrast (high noise) and 20% (low noise). We fitted cumulative normal psychometric functions to the data and used the variance parameters as our estimate of sensory noise (5% = 115.85 deg2, 20% = 11.03 deg2). Data was compared to results from an experiment using a method of adjustment procedure with identical stimuli and contrast conditions. Serial dependence was quantified by determining the amount of influence previously shown stimuli have on the participants' response (5% contrast= 0.20, 20% =0.00). We found, consistent with the adaptive theory, the amount of sensory noise is important for predicting the amount of serial dependence observed. Our results indicate that quantifying the magnitude of sensory noise is important for interpreting the results of serial dependence and also that a 2AFC paradigm is an effective in method for quantifying the sensory noise in these experiments.

Acknowledgement: University of St Andrews

43.422 **Flexible visual memory encoding revealed by probing method** Arni Gunnar Asgeirsson[1](arnigunnarasgeirsson@gmail.com), Christian Barckmann[2], Sandra Dögg Þórudóttir[1], María Jóhannesdóttir Peteresn[1]; [1]University of Akureyri, [2]Aalborg University

Research on visual short-term memory buffers often relies on probing a location that was recently occupied by stimulus (e.g. letter, color patch or oriented bar). This method of probing stimuli in visual memory implicitly assumes that the spatial position of a stimulus is encoded along with other stimulus properties. However, this assumption may not always be correct, and when it is not memory capacity estimations will be biased. We present the results of 4 experiments where we compare the effectiveness of feature and spatial memory probes in masked brief-exposure memory tasks. We used 3 different stimulus sets: 1) oriented bars, 2) letters, and 3) silhouette figures of common items and animals. All stimuli were presented in unique colors. We compared performance in a 2AFC orientation judgment and precision orientation judgments of bar stimuli, and identification of letter and figure stimuli. The results show that a feature-probe (color) is more effective than a spatial probe when subjects report the orientation of a bar stimulus with high-precision, but did not benefit performance when subjects reported the coarse orientation of the same stimulus (lean left or right). Conversely, subject performed better when visual memory was probed with spatial probes during a letter identification task, but figure identification was not affected by probe type. This suggests that visual short-term memory has a degree of flexibility in terms of which stimulus properties are encoded. It highlights the need to consider which type of probe will maximize the retrieval from visual memory to get the best available approximation of absolute memory capacity. Failing to consider this aspect of the research design may systematically underestimate the capacity of memory buffers.

43.423 **The efficacy of retroactive control of visual memory encoding depends on preceding oscillatory activities.** April E Pereira[1](april.pereira@mail.utoronto.ca), Keisuke Fukuda[1]; [1]Department of Psychology, University of Toronto Mississauga

Despite the virtually unlimited capacity of visual long-term memory, our ability to encode new visual information into this offline storage fluctuates from moment to moment, thus rendering some information forgotten later in time. Is there any way to monitor this moment-to-moment fluctuation and correct them when needed in real time? Previously we have demonstrated that we can monitor this fluctuation from multiple electroencephalograms (EEG) measures of memory encoding in real time and intervene failed memory encoding by providing re-encoding opportunities for stimuli that were predicted to be poorly encoded by the EEG measures (Fukuda & Woodman, 2015). However, it is unclear whether we can voluntarily change the fate of failed memory encoding without providing re-encoding opportunities. To test this, we recorded participants' EEG while they were sequentially presented with 600 pictures of random objects to remember. Importantly in a third of the trials, a post-stimulus cue was presented to prompt participants to try harder to encode the preceding stimulus. Our results replicated our previous findings that power of occipital alpha (8-14Hz) and frontal theta (5-7Hz) activities during encoding predicted the quality of memory encoding. More importantly, participants successfully upregulated the memory encoding for cued items even when the EEG indices measured prior to the cue onset predicted failed encoding (i.e., strong occipital alpha power and weak frontal theta power). Interestingly, the magnitude of post-stimulus cueing benefit depended on the frontal theta power but not on the occipital alpha power measured prior to the cue onset. More specifically, weak frontal theta power induced larger cueing benefit than strong frontal theta power, but the alpha power did not differentiate the magnitude of cueing benefit. These results not only demonstrate another approach to intervene our failed memory encoding but also suggest dissociative cognitive mechanisms underlying the two EEG indices of memory encoding.

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43.424 **The magical number 4 limits selection of object categories for encoding into visual long-term memory** Derek K McClellan[1](derek_mcclellan3@mymail.eku.edu), D. Alexander Varakin[1], Amanda J Renfro[2], Jason Hays[2]; [1]Eastern Kentucky University, [2]Florida International University

Previous research suggests that intentional encoding instructions may lead to improved performance on recognition memory tests via generic-attentional mechanisms rather than encoding-specific mechanisms (Varakin & Hale, 2014, SageOpen). Since attention is limited in capacity, the benefits of intentional encoding instructions should be too. The current experiment was designed to test for such capacity limits. During a study phase, participants (N = 472) were shown a series of objects from different categories (e.g. birds, cars, chairs, etc.), displayed one at a time at the center of a computer display. Participants were instructed to perform one of two tasks: memorizing the appearance of certain categories, or keeping a running count of certain categories. To examine capacity limits, the

 See page 3 for Abstract Numbering System

number of categories relevant to the task was 1, 3, or 5. On a subsequent yes/no recognition test, participants were presented with objects from two categories, one that was relevant during study and one that was irrelevant during study. Two findings reinforce the idea that intentional encoding instructions operate via generic attentional mechanisms. First, the effect of task (memorize vs. count) was not significant, despite the large sample size. Second, the interaction between the number of relevant categories during study, and object relevance at test was significant ($p < .01$). Participants who memorized/counted either 1 or 3 object categories were better at recognizing previously task-relevant objects than task-irrelevant objects. However, when 5 object categories were relevant at study, there was no effect of task relevance at test. This result is consistent with the idea that the limit of attentional selection is about 3 or 4 (Cowan, 2000, Behavioral and Brain Sciences), as the benefits of task-relevance diminished when participants were asked to count or memorize 5 object categories.

43.425 **Characterizing Memory Allocation Strategies in Transsaccadic Integration** Jennifer L Bittner[1](jennifer.bittner@rutgers.edu), Melchi M Michel[1]; [1]Rutgers University

When searching the visual world, memory must be allocated across eye movements (i.e., saccades) to make efficient use of the visual information available. Past research of transsaccadic memory has focused on comparisons with visual short-term memory (e.g., Bays & Husain, 2008, Irwin 1991, 1992) and measurement of transsaccadic memory capacity in visual search (e.g., Kleene & Michel, VSS 2017). Our project takes a further step, explicitly characterizing the temporal allocation of memory across multiple fixations. In particular, we used a multi-fixation temporal integration task to determine how humans use visual information as a function of (1) the temporal position of a fixation within a sequence of saccades, and (2) the set size, or number of locations to be encoded. In two experiments, participants were asked to report the average luminance polarity ('bright' or 'dark') of a Gaussian blob whose luminance varied over four sequential frames. The blobs were presented at one, two, four, or six locations and the target location was cued at the end of the trial. In Experiment 1, we simulated saccades by inserting blank intervals between stimulus frames, with the observer maintaining a central fixation. In Experiment 2, participants performed a set of actual saccades between two fixation points while the luminance blobs were presented. Using reverse correlation, we characterized the contribution of each display frame to the observer's luminance polarity decision and how the temporal pattern of contributions changed as a function of set size. Results from both experiments show a recency effect. Information from later fixations contributes more to the luminance polarity decision than does information from earlier fixations. However, the strength of this recency effect depends critically on memory load. It is enhanced with increasing set size and attenuated with decreasing set size, virtually disappearing when observers need only encode a single location.

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43.426 **Implicit ensemble bias in feature recall** Ke Tong[1](ketong@mail.usf.edu), Chad Dubé[1]; [1]University of South Florida

Ensemble representation is thought to facilitate visual processing and avoid information overload, but it may also bias the representation of individual items. When asked to adjust a probe to match the feature of a single target stimulus, subjects' responses were biased towards the mean of previously viewed but task-irrelevant stimuli, without any explicit requirement of engaging ensemble representation. We asked whether this obligatory bias towards the mean occurs across different categories of stimuli and tested it using two visual features (line length and spatial frequency). Our results showed that the bias towards the mean was evident in spatial frequency. However, we did not find a consistent bias towards the mean in line length in multiple conditions with different starting probe values, probe locations, and distributions of the overall stimuli. This may suggest a specificity of stimulus type of the implicit ensemble bias.

43.427 **Perceptual blurring and recognition memory: A differential memory effect in pupil responses** Hanae Davis[1](davishc@mcmaster.ca), Ali Hashemi[1], Bruce Milliken[1], Patrick J Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University

Perceptual degradation of visual stimuli decreases performance in many tasks. In word-reading, response time (RT) for words with no blur (NB) are slightly faster than for words with low blur (LB) and much faster than for words with high blur (HB). However, subsequently probing recognition memory for these words reveals superior memory sensitivity for HB words than NB words, and numerically worse memory for LB words than NB words. (Rosner, Davis & Milliken, 2015). This result suggests that a high level of perceptual degradation can enhance long-term memory, perhaps due to the upregulation of attention in response to processing difficulty at the time of encoding. Borrowing from the literature on pupil dilation as an index of mental effort (e.g., Beatty, 1982), we incorporated pupil size as a measure of attentional engagement in the present study. In the encoding phase, half of the participants were presented with NB and LB words intermixed, and the other half with NB and HB words intermixed. In the test phase, participants completed a surprise recognition memory task. Pupil size was recorded throughout the experiment. As expected, RT in the encoding phase increased with stimulus blur. More important, recognition memory in the test phase (relative to NB words) was slightly worse for LB words and significantly better for HB words. Evoked pupillary response (EPR) during the encoding phase did not differ between NB and LB words, but was larger for HB than NB words. Critically, the larger EPR to HB words at study was driven by 'old' words that were later recognized (hits), rather than those that were not (misses). Follow-up analyses showed the EPR results did not depend on longer time-on-task (slower RT) for HB words. The results are consistent with an attentional-upregulation account of the effect of perceptual degradation on long-term memory.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

43.428 **Decoding retrieved episodic memory in the prefrontal and parietal cortex** Gayoung Kim[1](gykim622@kaist.ac.kr), Sue-Hyun Lee[1,2]; [1]Department of Bio and Brain Engineering, College of Engineering, Korea Advanced Institute of Science and Technology (KAIST), [2]Program of Brain and Cognitive Engineering, College of Engineering, Korea Advanced Institute of Science and Technology (KAIST)

Retrieval of episodic memory allows us to bring previous experiences back to mind. Although it is considered that episodic memory contains information about the event and its context of occurrence, it remains unclear how these different contents are represented in the cortical regions during retrieval. To address this issue, we performed an event-related functional magnetic resonance imaging (fMRI) experiment comprising separate learning and retrieval sessions. During the learning session, participants were presented with 6 short movie clips. One day after the learning, the participants conducted the retrieval session inside the scanner. In this session, there were two retrieval tasks: event retrieval task and context retrieval task. During the event retrieval task, the participants were instructed to focus on recalling the core event while they were asked to attend to the recall of the context in which the event took place. We found that the same cortical regions, including prefrontal and parietal areas, were activated in both retrieval tasks, and the contrast between the activation maps of the event and context retrieval tasks revealed no significant differences. However, based on multivariate pattern analysis, we found that the response patterns of lateral prefrontal and parietal regions could be used to decode individual movies during the event retrieval task whereas the decoding was successful in a small region on the inferior parietal cortex but not in the prefrontal or other parietal regions observed in the event retrieval task. These results suggest that while a general retrieval network is engaged in the retrieval process regardless of the nature of the recalled content, distinct cortical regions are recruited to represent different elements of an episodic memory.

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43.429 **Context-based competition during memory retrieval triggers forgetting** Stephanie Jeanneret[1](stjeanner@utexas.edu), Evan Roche[1], Augustin Hennings[2], Anthony Dutcher[2], Mark Hollenbeck[3], Jarrod A Lewis-Peacock[1,2,3,4]; [1]Department of Psychology, [2]Institute for Neuroscience , [3]Department of Computer Science, [4]Center for Learning & Memory

Recent memory models highlight the importance of contextual information for remembering episodic events (Polyn et al., 2009). A consequence of binding event memories with their context is that contextually-related memories can interfere with the retrieval of targeted memories, leading to retrieval-induced forgetting (RIF) of the competing memories (Anderson et al., 2000). A model built to explain this effect describes a non-monotonic "U-shaped" relationship between memory activation and changes in memory strength (Norman et al., 2007). Specifically, competing memories that activate to a moderate degree (vs. low or high activation) are more likely to be weakened and subsequently forgotten. However, the factors governing whether and how memories will activate and compete during retrieval are not well understood. Here we test the hypothesis that events experienced closer in time will be more likely to compete and later get weakened in the process during memory retrieval. Various forms of multivariate pattern analyses of fMRI data were used to track memory reactivations of previously learned objects in the ventral visual cortex during a context-based cued-retrieval task. Preliminary results indicate that temporal distance during encoding did not systematically bias the degree of memory reactivation during context-based retrieval. However, we did find a non-monotonic relationship between reactivation strength and recognition performance: competing memories with the highest degree of reactivation (regardless of temporal similarity) were associated with lower subsequent memory performance. These results suggest that incidental reactivation of contextually-related memories during retrieval can trigger forgetting. To replicate and extend these results, we have modified the experimental design to include repeated retrieval attempts (3 per target item) (Kuhl et al., 2007), and a recognition-induced forgetting manipulation (Maxcey & Woodman, 2014) to more reliably induce forgetting of the competing memories. These results provide new understandings of the dynamics of memory competition during retrieval and its impact on forgetting.

43.430 **Effects of title wording on memory of trends in line graphs** Anelise P Newman[1](apnewman@mit.edu), Zoya Bylinskii[1], Steve Haroz[2], Spandan Madan[3], Fredo Durand[1], Aude Oliva[1]; [1]CSAIL, MIT, [2]ISIR, Sorbonne University, [3]SEAS, Harvard

Graphs and data visualizations can give us a visual sense of trends on topics ranging from poverty, the spread of diseases, the popularity of products, etc. What makes graphs useful is our ability to perceive these trends at-a-glance. Related work has investigated the effect of different properties of graphs, including axis scaling, the choice of encoding, and the presence of pictographic elements (e.g., Haroz et al. 2015) on the perception of trends or remembered size of the quantities depicted. Previous work has shown that visual attention is directed towards the text and specifically titles, which can affect what is recalled from memory (Borkin, Bylinskii, et al. 2016; Matzen et al. 2017). In a more controlled setting, we investigate how wording in a line graph's title impacts memory of the trend's slope. We designed a set of experiments that consist of first showing participants a simple graph with an increasing or decreasing trend, paired with a title that is either strongly stated ("Contraceptive use in Senegal skyrockets") or more neutral ("Contraceptive use in Senegal rises"). To avoid rehearsal, participants then performed a challenging task, before being asked to recall the title and answer a question about the graph's initial/final value or an extrapolated value. Can we change a participant's memory of a graph by modifying some accompanying text? These experiments bear resemblance to the eyewitness testimony experiments by Loftus et al. (1996). In some conditions, the strength of the wording in the title affects how participants recall the trend from memory, but this effect is not universal across experiments. Results of these experiments have important implications for how text interacts with long term visual memory and may bias future inferences.

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Perception and Action: Arm movements and tools

Monday, May 21, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.431 **Relative Phase Coordination at 90o Does Not Exhibit Phase Switching, as Does 180o** Rachel A Herth[1](raaneal@indiana.edu), Winona Snapp-Childs[1], Geoff P Bingham[1]; [1]Psychological and Brain Sciences, Indiana University

Without training, people can only perform two modes of rhythmic coordination stably – 0o and 180o relative phase. For both bimanual and unimanual coordination, as frequency increases, stability decreases, and performance of 180o phase switches to 0o. With training, people learn other coordination patterns, including 90o. In the current study, we tested whether skilled performance of 90° coordination would exhibit phase switching with frequency scaling, as does 180°. Participants were trained to perform 90o bimanually, at 0.75 Hz until they reached a mean proportion of time spent at 90o +/- 20o of 0.60 across 24 trials. Then, after 5 practice trials performing 90o unimanually, participants completed two series of trials with frequency scaling performing 90o bimanually and two unimanually. In one series of each condition, participants viewed the joysticks they were moving and in the other they viewed moving dots on a display controlled by the joysticks. Results showed no difference in mean performance between joystick and display conditions. 90o coordination did not exhibit phase switching to 0o or 180o as frequency increased. In agreement with previous studies, bimanual performance was better than unimanual. We divided the data into 20o relative phase bins from 0o to 180o to reveal the time spent at each relative phase. Unimanual and bimanual conditions exhibited different distributions, with bimanual showing greater proportions of time spent in the phases close to 90o and unimanual showing more evenly distributed times across all phases. Unimanual performance also showed a significant effect of frequency within each phase bin, with better performance at 1 and 1.25 Hz, while bimanual performance showed no difference. Increasing frequency did result in lower stability for unimanual as compared to bimanual performance. The lack of phase switching likely indicates use of different information to perform 90o as compared to 0o and 180o.

43.432 **Visual Biases Near Hand-held and Remotely Controlled Tools** Robert McManus[1](robert.r.mcmanus@ndsu.edu), Laura E. Thomas[1]; [1]Center for Visual and Cognitive Neuroscience, Department of Psychology, North Dakota State University

Previous work has shown that observers are faster to detect targets appearing near the hands than they are to detect targets appearing outside of peripersonal space. Interestingly, target detection is also facilitated in the space around a hand-held tool (e.g., Reed et al., 2010). Presumably, these visual biases occur because active, goal-directed use of hand-held tools expands representations of peripersonal space to incorporate the functional action area around the tool. In this project, we explore whether this same phenomenon can apply to remotely controlled tools. Although both hand-held and remotely controlled tools expand the area in which users can successfully perform actions, only remotely controlled tools create action areas that are non-contiguous with the body. Across two experiments, we measured participants' reaction times to detect targets appearing near or far from a hand-held tool (Experiment 1) or a remotely controlled drone (Experiment 2). Prior to visual testing, participants in both experiments used the tools to rake sand, expanding action space. Replicating previous findings, we found that after active tool use, participants in Experiment 1 were facilitated in detecting targets appearing near a hand-held tool. However, participants in Experiment 2 showed no difference in target detection speed for targets appearing near and far from the drone. These results suggest that goal-directed action may not be sufficient to introduce visual biases near a tool, but instead that these biases occur only for tools that are contiguous with the body.

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43.433 **The effect of prolonged exposure to feedback delay on body ownership, agency and presence in virtual reality** Loes CJ van Dam[1](lvandam@essex.ac.uk), Josie R. Stephens[1]; [1]Department of Psychology, University of Essex

Monday AM

When interacting with virtual environments, feedback delays between making a hand movement and seeing the visual consequences of that movement are detrimental for our senses of body-ownership, agency and presence. However, to date it is unknown whether prolonged exposure to the delay, and thus the possibility to adapt to it, leads to the recovery of these senses. Here we investigated the immediate effects of an added feedback delay of 200 ms on ownership, agency and presence, as well as the effects of prolonged exposure to the delay. Participants performed a predictable target-tracking task (see Rohde, van Dam & Ernst, Journal of Vision, 2014) in a virtual reality environment. We measured the participants' performance in terms of behavioural lag and spatial errors with respect to the target in both no-delay and added-delay conditions. Additionally, participants rated their sense of ownership, agency and presence on each trial using sliding scales. These single trial ratings were compared to the results of the more traditional questionnaires for ownership and agency (Kalckert & Ehrsson, Frontiers in Human Neuroscience, 2012) and presence (Schubert, Friedmann & Regenbrecht, Presence: Teleoperators and Virtual Environments, 2001) for both no-delay and added-delay conditions. We found that the participants' single trial ratings corresponded very well to the results of the traditional questionnaire measures for both the no-delay and added-delay conditions. Moreover, not only did participants behaviorally adapt to the delay over time, their senses of ownership and agency significantly improved with prolonged exposure to the delay as well. The sense of presence showed a smaller detriment as a result of the added delay and therefor a smaller trend towards prolonged exposure being effective. Together the results suggest that there is a tight link between the ability to perform a behavioral task and the sense of ownership and agency in virtual reality.

43.434 **Sensitivity to Illusory Target Motion in Elderly and Association with Problems in the Activities of Daily Life** Alix L de Dieuleveult[1,2,3](alix.dedieuleveult@tno.nl), Anne-Marie Brouwer[2], Petra C Siemonsma[4,5], Jan BF van Erp[2,3]; [1]Predictive Health Technologies, TNO, Leiden, Netherlands, [2]Perceptual and Cognitive Systems, TNO, Soesterberg, Netherlands , [3]University of Twente, Enschede, Netherlands , [4]Thim van der Laan, University for Physiotherapy, Nieuwegein, Netherlands, [5]University of Applied Sciences Leiden, Leiden, Netherlands

A horizontally moving background makes a downward moving disc appear to move in the opposite direction of the background. Using a large touch screen and a disc interception task, we showed that healthy older adults (OA) are more influenced by this illusion than younger adults (YA). This is possibly related to a reduced ability to ignore irrelevant sensory information, and thus to sensory integration. Sensory integration is crucial to perform the activities of daily living (ADLs). Therefore, the tapping test could help diagnose sensory integration issues and predict future ADLs problems in OA. We examined whether initial lab results could be replicated using a mobile version of the test on a tablet and whether issues in ADLs are associated with stronger effects of the illusion. Nineteen healthy YA and twenty-four OA with a range of ADLs difficulties were tested (fifteen considered as fit OA and nine considered as unfit because they could not perform all the conditions of the experiment). The illusion effect was replicated for YA but was smaller in fit OA compared to YA. This discrepancy increased when proprioceptive or cognitive dual tasks were performed. These results might be explained by the fact that OA tend to hit in the middle of the tablet regardless of the direction of motion of the disc and the background. Unfit OA showed a reverse illusion effect compared to YA (in the direction of being 'dragged' by the background rather than in the direction of illusory target motion). The failure to fully replicate the lab results may be due to increased task difficulty. Nevertheless, correlations were found between various aspects of tapping performance and participants' scores in ADLs tests, which suggest that the mobile interception test may be useful as a diagnostic test of ADLs issues.

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43.435 **Perceive Bigger, Hit Better** Misong Kim[1](msongkim@hallym.ac.kr), Seung-hoon Choi[1], Hwa-kyoung Jung[1], Na-ri Jung[1], Hoon Choi[1]; [1]Department of Psychology, Hallym University

Visual perception is one of the most important factors in sports, because sensory–motor coordination is a major competence of sports athletes. Some researchers have found that when sports players are confident, they perceive the ball as bigger and perform better. But what about the opposite way? If sports players perceive the ball as bigger, does that illusion increase their confidence, resulting in better performance? In the current study, we explore whether the perceived size of a golf ball affects golf shots. To manipulate the perceived size of the golf ball, we employed golf balls with three types of patterns: a regular golf ball, a soccer ball pattern, and a baseball pattern(Supp. Fig. 1). In Experiment 1, we measured the perceived size of each patterned golf ball. The results showed that the soccer-patterned and baseball-patterned balls were perceived as bigger than the regular balls. In Experiment 2, we examined the effects of the illusion induced by the patterns on the golf balls on actual golf shots. We measured the driving distance and accuracy after participants hit each patterned ball. Although there was no significant difference in driving distance, we found a significant difference in accuracy: participants were more accurate with patterned balls than with a regular ball. These results imply that the illusion induced by the golf ball patterns affects the actual golf shot, suggesting that visual perception can be a useful tool for improving sports performance or developing effective training methods.

Acknowledgement: NRF-2017S1A5A8021943

43.436 **Influence of background optical illusions on guided hand movements** Kazuki Konno[1](i140274b@yokohama-cu.ac.jp), Ruggero Micheletto[1]; [1]Yokohama City University, International College of Art and Sciences

How does visual guidance is perturbed by background ambiguous illusory visual information ? We study how the visual/motor system is affected by the presence of optical illusions in the background of images relevant to a motor task. We developed an experimental setup in which a subject is requested to move an object on the screen of a computer in controlled conditions. The task assigned was to move precisely the mouse along a narrow path plotted on a background where optical illusions of different types are (or are not) present. Our software monitors the position of the mouse and the exact timing of the subjects movements. The software is developed originally using an open source visualization package called Blender. Several optical illusion were tested. We found that a background pattern with a modified version of the Hering illusion had the strongest influence on the hand visual-motion coordination. A set of 4 backgrounds based on illusory images (two types of Hering patterns and two types of colorful motion illusion) were tested on 8 subjects. We found that the presence of these images in the background perturbs somehow the visual-motor coordination and produced a statistically significant reduction of performance speed for the Hering illusion. Performance times were up of about 2 seconds, the task that requires about 20 second in total. This difference was statistically validated by t-test analysis averaging on 8 different subjects that performed the same tests with same patterns. Movement speed was also reduced of about 20% in average. This experiment of interest to clarify the fundamental mechanisms involved in visual-motor coordination and also it has possibly implications on other real-life activities where visual information guide hand movements, like driving a car, moving a mouse or catching an object. Background is important!

Acknowledgement: YCU Basic Research Fund

43.437 **Is deciding to act or executing the action critical for the action effect?** Blaire J Weidler[1](blaire.weidler@gmail.com), Richard A Abrams[2], Jay Pratt[1]; [1]University of Toronto, [2]Washington University in St. Louis

Recent research has revealed that a simple action can affect subsequent visual search. More specifically, after making a keypress to an object, participants are faster to find an unrelated target in a visual search task if it happens to share a feature (e.g., the color) of the acted-on object (pattern referred to as the action effect). However, it remains an open question as to what specifically is driving this effect – is it the decision to make an action or the execution of the motor response? To disentangle these possibilities, on each trial participants in the present experiments decided if a feature of an object matched a previously seen word (e.g., BLUE or SQUARE): if it matched, they pressed a key, if it did not they viewed the object. Importantly, the color of the object changed (e.g., from blue to red) shortly after its onset. The timing of the change was such that

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participants planned the action (i.e., decided to act) while one feature value was present, but executed it after the object's feature changed. Thus, we could independently evaluate the contributions of the "decision" and "motor" components to the action effect: In the subsequent visual search task (participant searched for a tilted line on each trial) on some trials the "decision" color was present in the search display whereas on other trials the "motor" color was present. Orthogonal to that manipulation, sometimes that color validly predicted the orientation target's location whereas sometimes that color was present but contained a distractor (i.e., was invalid). The action effect was larger when the decision color appeared in the search task. Thus, these data indicate features of the object present when a decision to act is made bias subsequent search to a greater extent than features present at the time of the action.

43.438 **Transfer of visuomotor adaptation between eye and hand tracking** James Mathew[1](jamesmathew07@yahoo.com), Cedric Goulon[2], Frederic Danion[1]; [1]Institut de Neuroscience de la Timone, CNRS-PACE, Aix-Marseille University, [2]Institut des Sciences du Mouvement, CNRS, Aix-Marseille University

Prediction turns motor commands into expected sensory consequences, whereas control turns desired consequences into motor commands. Flanagan and colleagues (2003) have shown that subjects can learn to predict before they can actually learn to control. This observation was interpreted as evidence that the update of prediction precedes control in motor learning. Here we investigated the transfer of learning between two visuomotor tasks both requiring adaptation to a 90° rotation. In the first task participants had to track with their eyes a self-moved target whose displacement was driven by random hand motion (see also Landelle et al., 2016). In the other task participants had also to move the hand but this time they were required to move a cursor so as to track an externally moving target (see also Ogawa & Imamizu, 2013). The first task was designed to test the ability of participants to predict novel visual consequences arising from their hand actions (eye tracking task). The second task was designed to monitor their ability to control a cursor along a desired trajectory (hand tracking task). Our preliminary results suggest an asymmetrical transfer of learning between the two tasks. Namely, although prior experience in the hand tracking task enhanced performance in the eye tracking task, prior experience in the eye tracking task did not improve performance in the hand tracking task. A possible scheme to account for these results is that visuomotor adaptation in our hand tracking task requires both the update of a forward and inverse model (Wolpert & Kawato, 1998), whereas adaptation in our eye tracking task relies solely on the update of a forward model. At a more general level these results emphasize that our ability to predict sensory consequences of hand movements can be improved without necessarily improving our ability to control hand movements.

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43.439 **Different ways of correcting for previous temporal errors in interception tasks.** Joan López-Moliner[1](j.lopezmoliner@ub.edu), Cécile Vullings[2], Laurent Madelain[2], Robert J van Beers[3]; [1]Institut de Neurosciences (UBneuro) Universitat de Barcelona, [2]SCALab Université Lille 3, [3]Vrije Universiteit Amsterdam

Correction on the basis of previous errors is paramount to sensorimotor learning. While corrections of spatial errors have been studied extensively, little is known about corrections of previous temporal errors. We tackled this problem in different conditions involving hand movements (HM), saccadic eye movements (SM) or button presses (BP). The task was to intercept a moving target (3 possible velocities) at a designated zone (i.e. no spatial error) either with the hand sliding a pen on a graphics tablet (HM), a saccade (SM) or a button press (BP) that released a cursor moving ballistically for a fixed time of 330 ms. The dependency of the final temporal error on action onset varied from "low" in HM (due to possible online corrections) to "very high" in the BP condition. We analyzed the lag-1 autocorrelation (acf(1)) of action onset and the dependency on previous errors to study how trial-by-trial corrections were made. In conditions SM and BP, acf(1) was not different from zero denoting an optimal correction, while subjects under-corrected (acf(1) >0) in the HM condition. Interestingly, in conditions SM and BP action onset did not depend on the previous temporal error, but it did in the HM condition. However, this dependency was clearly modulated by the duration of movement time as faster movements depended less on the previous actual temporal error. One explanation for how subjects corrected in SM, BP and HM involving fast movements would be that they used the predictive error (i.e. intended action onset minus actual action onset). An analysis using a Kalman filter confirmed that our results are consistent with the time of action onset being driven by the predictive error. The type of temporal error that is used seems to depend on the possibility of exerting online control during the interceptive movement.

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43.440 **Priming with flash-lag illusion is percept-dependent** Marjan Persuh[1](mpersuh@bmcc.cuny.edu), Dinara Guliyeva[1]; [1]Borough of Manhattan Community College, The City University of New York

An influential proposal suggests that response priming is independent of awareness, depends on rapid feedforward sweep of visual information processing and depends on physical characteristics of the stimulus. We tested some of these hypotheses using a well-characterized flash-lag illusion: when a static stimulus is briefly presented in alignment with a moving stimulus, it is perceived as lagging behind it. This illusion is especially well suited for testing the hypotheses about priming for the following reasons: (1) it is very robust, (2) a large body of literature suggests that it is a high-level cognitive illusion and (3) it shows a strong dissociation between physical and perceived location. To prime for location, two horizontal bars, moving downwards or upwards were presented at the center of the display. A dot was then flashed between the bars. When bars were moving downwards, dot position was perceived above the bar and vice versa. Participants made speeded responses to targets, which followed primes and consisted of two static horizontal bars with dot positioned above or below them. If response priming is based on physical characteristics of the stimulus no priming would be expected because dot was spatially aligned with the bars. Our data revealed strong location priming, demonstrating that response priming depends on the percept and not the physical characteristics of the stimulus. There was no priming for moving bars alone. Because flash-lag illusion is considered high-level cognitive phenomenon, our data further suggest that visual system rapidly computes perceptual quality of the stimulus, which can affect even fast motor responses.

Spatial Vision: Crowding and eccentricity

Monday, May 21, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.441 **Visual crowding effect in the Parvocellular and Magnocellular visual pathways** Nilsu Atilgan[1](atilg001@umn.edu), Sheng He[1]; [1]University of Minnesota

A key function of the human visual system is to recognize objects, and often in the visual periphery. However, an object that is easily recognized on its own could become unrecognizable if surrounded by other objects, especially in peripheral vision. This detrimental effect of nearby objects on visual discrimination of a target object is known as crowding. Even though there have been numerous studies that have investigated crowding phenomenon, its neural substrates remain unclear. Previous studies have primarily focused on finding the stage(s) in the visual hierarchy where crowding starts to limit target processing, with little attention directed to potential differences of the crowding effect in different visual pathways. The current study investigated the nature of crowding with stimuli designed to separately engage the Parvocellular (P) or Magnocellular (M) pathway, by tuning stimulus features for the targeted pathway and using background to saturate the other pathway. The critical spacing of crowding, that is the minimal distance between target and flanking objects that allows identification of the target object, was measured. The smaller critical spacing indicates weaker crowding effect. Participants completed an orientation detection task at 8° eccentricity in the P and M pathway conditions while inter-stimulus spacing was varied (ranged 0.9°-4.4°). Results show, consistent among all subjects, that the critical spacing of crowding is smaller in the P pathway than that in the M pathway, suggesting that the crowding effect is more severe in the M than in the

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P pathway. This result may reflect the fact that at the same eccentricity, neurons in the P pathway tend to have smaller receptive fields than that in the M pathway.

43.442 **Characterizing neural processing in foveal primary visual cortex** Felix Bartsch[1](fbartsch@umd.edu), Daniel A Butts[3], Bruce G Cumming[2]; [1]Department of Biology, College of Behavioral and Social Sciences, University of Maryland, [2]Laboratory of Sensorimotor Research, National Eye Institute, National Institute of Health, [3]Department of Biology, College of Behavioral and Social Sciences, University of Maryland

Visual processing in the fovea (center-of-gaze) is central to human perception, yet most neurophysiological studies of neural processing focus on neurons in the parafovea (>2 degrees eccentricity). This is because the small receptive fields in the fovea have a higher resolution than conventionally used eye-tracking hardware accounts for, making detailed assessment of receptive field properties unreliable. Here, we recorded V1 neurons at eccentricities varying from 0 to 16 degrees of visual angle in awake, fixating macaque monkeys during presentation of a temporally varying random bar stimulus. We used a model-based eye-tracking algorithm to accurately correct for fixational eye movements, allowing for the determination of detailed receptive field properties. To measure these, we fit nonlinear cascade models to the recorded responses, which provided detailed information about their spatiotemporal processing, as well has how multiple "subunits" – each selective to a different spatiotemporal feature – combine nonlinearly to best predict the observed response. Our preliminary analysis of these model-based results shows that as eccentricity increases, models required a larger number of subunits that are more spatially dispersed, consistent with observations that the average overall receptive field size also increased. Surprisingly, we found that the spatial and temporal frequency tuning properties of individual subunits comprising the models had a much weaker dependence on eccentricity. This study thus provides the first detailed comparisons of visual processing between foveal versus parafoveal neurons.

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43.443 **Appearance of complex stimuli in the peripheral visual field** Matteo Valsecchi[1](matteo.valsecchi@psychol.uni-giessen.de), Jan Koenderink[1,2], Andrea van Doorn[1,2], Karl R. Gegenfurtner[1]; [1]Department of Psychology, Justus-Liebig-University Giessen, [2]Laboratory of Experimental Psychology, University of Leuven

Measuring the appearance of peripheral stimuli is a challenging task, given that the drawing and verbal abilities of naïve observers limit the extent to which they can characterize it. We used the eidolon factory (Koenderink et al., JOV 2017), an image-manipulation algorithm based on a formal description of the visual field, in order to provide our observers with a meaningful perceptual space where peripheral appearance can easily be matched. In particular we concentrated on the space defined by the reach and coherence parameters of the eidolon factory, which control the amount of distortion and the degree to which the distortion is applied in a coherent way across scales. Different configurations of the parameters can produce stimuli which are distorted but sharp or distorted and fuzzy. We had 12 observers reproduce in foveal viewing the appearance of images viewed peripherally (20° or 30°) by adjusting the coherence, reach or the combination of both in different trials. The peripheral images were depictions of ensembles of geometric shapes that were perturbed with the eidolon factory (.5 coherence and an arbitrary reach). Observers showed a significant tendency to adjust the centrally viewed stimuli with higher coherence and lower reach when the peripheral stimulus was viewed at 20° and 30°, that is, they reported a regularized appearance. These biases were absent in a control condition where observers looked directly at both stimuli. Our results confirm and extend the phenomenon of sharpness overconstancy in peripheral vision, showing that the fact that we have positional uncertainty and reduced sensitivity for higher spatial frequencies in peripheral viewing by no means lets our peripheral visual field appear distorted and blurred. On the contrary, as the sensory evidence for the contrary is reduced, our visual system generates the impression of a world where boundaries are straight and sharp.

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43.444 **Do you see how many I see? Quantifying human crowd counting accuracy over natural scenes** Logan Blake[1](loganblake@knights.ucf.edu), Ali Borji[2]; [1]University of Central Florida, Burnett School of Biomedical Sciences , [2]University of Central Florida, Department of Computer Science

Previous research (e.g., Cicchini et al., 2016, Lee et al., 2016) has shown that humans can reliably estimate the number of items in simple synthetic arrays (a.k.a numerosity). However, the extent to which this capacity generalizes to complex realistic scenes remains unknown (e.g., presidential inaugural photos). Here, we aim to quantify the accuracy of subjects in crowd counting. During the experiment, images are presented to subjects at short intervals of 5, 1, or 0.5 seconds (shuffled presentation; one time interval at a time). The subject must then report the number of people present in the crowd (discretized into 5 categories: 1-1K, 1K-2K, 2K-3K, 3K-4K, and 4K-5K) by pressing a corresponding key on the keyboard. Each image is succeeded by a white noise masking stimulus shown for 1 second, and a blank screen which remains for 10 seconds or until key press. Each category consists of 14 images that cover the whole crowd range in that category. Subjects were 12 undergraduates (6 male, 6 female) between 18 and 26 years old and had normal or corrected to normal vision. Analysis of the data shows that a) Average accuracy is significantly above chance (33% vs. 20%). Subjects are better over images with less than 1K people (55%), followed by images with more than 4K people (46%). The middle categories pose the most difficulty to subjects. In such cases, subjects are off by only one unit, and b) The more time, the better estimation accuracy. The average accuracy drops significantly with less presentation time (33.8%, 31.2%, and 27.85% for 5, 1, and 0.5 seconds, respectively). The drop is more severe going from 1 to 0.5 seconds. Our results show that humans are able to estimate numerosity over naturalistic stimuli with many items.

43.445 **The Effect of Multiple Object Tracking on Peripheral Crowding** Lilit G. Dulyan[1](lidulyan@gmail.com), Igor S. Utochkin[1]; [1]Higher School of Economics, Russia

Crowding is a phenomenon of peripheral vision that impairs the ability to individuate (perceptually separate objects from each other) and, as a result, to recognize an object surrounded by flankers (Intriligator & Cavanagh, 2001; Whitney & Levi, 2011). There is a long-living controversy in the literature between theories supporting or denying the role of attention in crowding (Yeshurun & Rashal, 2010; Scolari et al., 2007). In our study, we suggest a new experimental approach to addressing this issue. It is based on a dual-task paradigm allowing to manipulate attentional allocation towards or away from the crowded stimuli. As a primary task to manipulate attentional load, we used multiple object tracking (MOT) at the center of the visual field: participants either tracked few moving targets among 8 items (load), or passively observed motion (no load). The crowding task was secondary and required observers to recognize the orientation of a Landolt's ring, surrounded by two flanker rings (crowding) or alone (control). To keep the rings at fixed eccentricity, observers performed MOT looking at fixation and were eye-tracked. Both the optimal difficulty of MOT and the baseline crowding threshold (critical target-flanker distance) were measured for each individual observer. Our results show attentional load under MOT impaired the recognition of the target ring both when this target is presented alone (under load: M = 78.03% vs no load: M = 92.5%) or when it is flanked (under load: M = 56.4% vs no load: M = 66.5%) which indicates the general role of attention in extrafoveal vision. As load-induced decrements in the recognition rate were approximately equal in the crowded and the control conditions, we cannot draw a strong conclusion regarding a specific effect of attention on recognition of an object surrounded by flankers and on crowding.

Acknowledgement: Program for basic research at HSE

43.446 **Separating effects of texturization and segmentation in visual crowding** Cathleen M Moore[1](cathleen-moore@uiowa.edu), Marisol Lauffer[1]; [1]University of Iowa

Visual crowding refers to the deleterious effects of closely spaced stimuli (flankers) on the ability to identify targets. Increasing spatial separation between flankers and targets reduces crowding, as does increasing their featural differences. Rosen and Pelli (2015, JOV) showed that a reduction in crowding caused by contrast-polarity differences between target and flankers is nearly eliminated when outer flankers that match the target

are added to the display. Importantly, these outer flankers alone cause little crowding. This pattern crowding effect is similar to effects in which the perceptual organization of a display, rather than the immediately proximal stimulation near the target, seems to determine crowding (Manassi et al., 2015, JOV). Two alternative classes of explanation have been offered for these kinds of effects. Texturization accounts propose that crowding is caused by imprecision in the representation of image features following early filtering (Balas et al, 2009, JOV). A defining characteristic of texturization is that scene structure (e.g., figure-ground organization) is irrelevant in determining crowding. Segmentation accounts propose that crowding is caused by post-perceptual-organization confusion of target and flankers (Francis et al., 2017, Psy Rev), and display characteristics that facilitate target-flanker parsing will reduce crowding. A defining characteristic of segmentation is that scene structure is critical in determining crowding. We sought to test between texturization and segmentation accounts of pattern crowding by presenting opposite contrast-polarity flankers at close, medium, and/or far distances from the target while also manipulating the presence or absence of same contrast-polarity outer flankers. This created displays with varying target-flanker proximities and configural structures. Texturization predicts that the density and proximity of stimuli will determine crowding, whereas segmentation predicts that configural structure will determine crowding. The results are consistent with separate contributions from texturization and segmentation, suggesting that crowding effects derive from separate early and mid-level visual processes.

43.447 **Revealing the mechanisms underlying inner-outer asymmetry and visual crowding** Jun-Yun Zhang[1](zhangjunyun@pku.edu.cn), Gong-Liang Zhang[2], Cong Yu[1]; [1]School of Psychological and Cognitive Sciences, Peking University, [2]Department of Psychology, SooChow University

The outer flanker induces stronger crowding than does the inner flanker (Bouma, 1973). This classical yet unsolved mystery is considered a hallmark property of visual crowding. Here we tested a hypothesis that the roles of different crowding mechanisms may be responsible for the asymmetric crowding effects by inner and outer flankers. Observers reported a Sloan-letter target (7.5° eccentricity) that was flanked by either an inner or outer Sloan letter along the horizontal meridian. Crowding was quantified by threshold changes or critical spacing. Results: (1) When the target and flanker were randomly drawn from the same 5 Sloan letters, crowding was strongly asymmetric (baseline-normalized thresholds with an outer/inner flanker = 1.75/1.18); (2) When the target and flanker were each drawn from a separate 5-letter group and the observers were shown with a printed target list, to avoid stimulus confusion in visual memory, the corresponding thresholds changed to 1.57/1.14; (3) When the flankers were 10x10 scrambled, as well as replaced by same-sized black squares, to remove stimulus features, the corresponding thresholds further reduced to 1.19/1.14. (4) The Bouma factors with an outer flanker were 0.37, 0.26, and 0.13 in conditions 1-3, respectively. (5) When a flanker was placed above/below the target (tangential arrangement), the thresholds were unchanged (1.08-1.12) across conditions 1-3, and similar to unchanged thresholds with an inner flanker. Our results suggest: First, outer-flanker crowding consists of target-flanker confusion in visual short-term memory (grouping effect in 1-2), feature confusion (feature scrambling effect in 2-3), and lateral masking (3), while inner-flanker crowding includes lateral masking only. This difference explains inner-outer crowding asymmetry. Second, the Bouma factor can be divided into three components, each reflecting the effect of one crowding mechanism. Third, top/bottom-flanker crowding, like inner-flanker crowding, is caused by lateral masking and significantly weaker than outer-flanker crowding, which explains radial-tangential crowding asymmetry.

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43.448 **Age-related loss of retinal ganglion cells and its impact on spatial integration** Rong Liu[1](liur@uab.edu), MiYoung Kwon[1]; [1]Department of Ophthalmology, School of Medicine, University of Alabama at Birmingham, Birmingham, AL

Evidence has shown that the spatial extent of crowding increases with age (Liu & Kwon, 2017). It is also known that aging brings about approximately 15% to 25% loss of retinal ganglion cells (RGCs) even in the healthy eyes (Curcio & Drucker, 1993; Gao & Hollyfield, 1992). While RGCs, the output neurons of the retina, are likely to impose a fundamental limit on spatial integration properties, little is known about the role of RGCs in age-related changes in the extent of spatial integration. Here we investigated whether the age-related loss of RGCs is associated with the age-related increase in crowding zone and in Ricco's area (if any). The study included 15 young (mean age=23.4±4.2 years) and 7 older adults (mean age=59.9±5.8 years) with normal or corrected-to-normal vision. For each subject, the thickness of the macular RGC plus inner plexiform (RGC+) layer, known to be related to RGC density, was measured with Spectral-Domain Optical Coherence Tomography within the central 20 degrees visual field. Crowding zone (i.e., the minimum target-flanker spacing required for reliable target recognition) and Ricco's area (i.e., the area of complete spatial summation for reliable luminance detection) were also measured at various retinal locations within the central 20 degrees visual field. Our results showed that, compared to young adults, older adults exhibited a significant reduction in macular RGC+ layer thickness, but a significant increase in crowding zone and Ricco's area (all $p< 0.05$). Furthermore, macular RGC+ layer thickness was significantly correlated with both crowding zone ($r=-0.50$, $p=0.02$) and Ricco's area ($r=-0.44$, $p=0.04$). Taken together, our findings suggest that age-related loss of RGCs may in part explain age-related increase in spatial integration zone.

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43.449 **Crowding distance in healthy children.** Sarah J Waugh[1](sarah.waugh@anglia.ac.uk), Denis G Pelli[2,4], Leticia Álvaro[1,3], Monika A Formankiewicz[1]; [1]Anglia Vision Research, Department of Vision and Hearing Sciences, Anglia Ruskin University, [2]Psychology Department, NYU, [3]The Sussex Colour Group, School of Psychology, University of Sussex, [4]Center for Neural Science, NYU

Clinically, visual acuity is measured under "crowded" conditions to enhance inter-ocular acuity differences, thereby improving detection of amblyopia. A new clinical test (Pelli, Waugh, Martelli et al, 2016) measures the crowding distance (aka "critical spacing") anywhere in the visual field, including the adult fovea, where it is smaller (0.05 deg) than a 0.0 logMAR Sloan letter. There is a need to find out how crowding distance changes with normal development, to allow screening children for abnormal development of this key property of object recognition. Crowding distance and visual acuity were measured in 200 primary school children (3-11 years) and 16 adult participants, using 9-optotype forced-choice trials and an adaptive staircase. Crowding distance was determined for trigram (AXA) and repeated arrangements (AXAXAXA…) of the Pelli font. The ratio of horizontal spacing:optotype width was maintained at 1.4x, so size and spacing co-varied. From age 3 years to young adult, crowding distance dropped four-fold, from 0.22±0.03 to 0.05±0.01 deg (mean±SE) with normal development; whereas isolated letter acuity changed only two-fold from 0.10±0.05 to -0.22±0.03 logMAR (i.e. log 2 = 0.3 = 0.1 to -0.2). Crowding distance reached adult levels at age 8 years, slightly later than the 6 years for visual acuity. In normal children, the repeated arrangement yielded a similar crowding distance to the trigram, and its immunity to eye position may help in estimating crowding distance in children and adults with poor fixation. These estimates of normal crowding distance may allow enhanced screening of children for vision problems including amblyopia.

Acknowledgement: ARU Quality Related Research Funds

43.450 **Conservation of crowding distance in human V4** Jingyang Zhou[1](jyz205@nyu.edu), Noah C Benson[1], Jonathan Winawer[1], Denis G Pelli[1]; [1]Psychology department, New York University

Crowding — the inability to recognize objects in clutter — severely limits object recognition and reading. In crowding, a simple target (e.g. a letter) that is recognizable alone cannot be recognized when surrounded by clutter that is less than the psychophysical crowding distance away (deg). Prior work shows that crowding distance scales linearly with target eccentricity and varies with the direction of crowding: crowding distance is approximately double for flankers placed radially rather than tangentially. Multiplying the psychophysical crowding distance by the cortical magnification factor yields the cortical crowding distance (mm of cortex). In V1, radial cortical crowding distance is a fixed number of mm and conserved across eccentricity, but not across orientation (Pelli, 2008). Since crowding distance in V1 is conserved radially across eccentricity, we imagined that there might be some downstream area, more involved in crowding, where the crowding distance is isotropic, conserved across both eccentricity and orientation. METHOD: We measured psychophysical crowding distances on 4 observers at eccentricities of ±2.5°, ±5°, and ±10°, radially and tangentially, for letter targets on the horizontal meridian. Results confirmed the well-known dependence on eccentricity and orientation. Using anatomical and functional MRI, we also measured each observer's retinotopic maps, and quantified tangential and radial cortical magnification in areas V1-hV4. RESULTS & CONCLUSION: We find that all four areas conserve cortical crowding distance across eccentricity, but only hV4 conserves crowding distance across both eccentricity and orientation. After averaging measurements across observers (n=4), we find that the V4 crowding distance is 3.0±0.2 mm (mean±rms error across orientation and eccentricity). Across both dimensions, conservation fails in V1-V3, with rms error exceeding 0.7 mm. The conservation of crowding distance in hV4 suggests that it mediates the receptive field of crowding, i.e. the integration of features to recognize a simple object.

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43.451 **Repetitive visual pattern masking enlarges the perceived distance between stimuli (but does not diminish crowding)** Sabine Born[1](sabine.born@unige.ch); [1]Faculté de Psychologie et des Sciences de l'Education, Université de Genève, Switzerland

Many visual phenomena attest how masks reduce the visibility of a stimulus. But can masking also affect an object's spatial representation? In the current study, I explored effects of pattern masks on the perceived spacing between two clearly visible objects. On each trial, two pairs of bars were presented for a total duration of two seconds, one pair to the left, and one to the right of central fixation. Participants were asked to judge in which pair the two bars were further apart. The bars of a pair were either presented continuously, or they were flickering on and off in synchrony (at a frequency of 5 Hz), or they were presented alternating, giving the impression of one single object moving back and forth (apparent motion). With flickering or alternating bars, a pattern mask consisting of small grey squares of random luminance could be presented during the off-phases of the stimuli (50 ms). Although these masks may impoverish the representation of the bars, they remained perfectly detectable due to their long and repetitive presentation. Surprisingly, with masking, the distance between the two bars was overestimated when compared to an equivalent pair presented without mask on the other side. But also when pitted against a continuously presented pair of bars, a strong and robust bias emerged to report the distance between the masked bars as larger. Following up on this effect, I reckoned that if pattern masking enlarges the perceived spacing between objects, it may also diminish crowding. In a first pilot experiment, this was not the case. Quite to the contrary, a similar repetitive masking procedure led to poorer performance in a crowding setup. The stimuli in the masked and unmasked conditions were not equated for visibility, though, which may explain the disruptive effect of the masks on identification accuracy.

Color and Light: Cognition and preference

Monday, May 21, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.452 **Sound symbolism expressing visual texture on different linguistic backgrounds** Kohta Wakamatsu[1](wakamatsu16@vpac.cs.tut.ac.jp), Jinhwan Kwon[2], Maki Sakamoto[2], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Department of Informatics and Engineering, The University of Electro-Communications

We associate certain sounds with certain psychological concepts such as size and sharpness. This phenomenon is called sound symbolism, and some sound-symbolic words have universality regardless of different linguistic background as shown in Bouba-Kiki Effect (Ramachandran & Hubbard, 2001). Here we investigated whether universal sound-symbolic words expressing visual texture exist, using International Phonetic Alphabet (IPA) features, which reflects the movement of our speech organs. We used 1946 material images obtained from Flickr Material Database (Sharan et al., 2014). In experiment 1, Japanese native speakers were asked to rate the 14 texture measures (e.g., glossiness and roughness) using visual analog scale from each image and asked to express its impression using sound-symbolic words. We performed multiple regression analysis to predict perceptual quality rating value (14 texture measures) based on 17 IPA features of the obtained sound-symbolic words. As a result, some perceptual qualities such as glossiness corresponded to visual dominance, and roughness corresponded to tactile dominance were significantly explained ($R2=0.65$, 0.68, respectively). This result suggests that perceptual qualities perceived from visual image are linked to the IPA features of sound-symbolic words expressing texture impression. In Experiment 2, we used eight tangible materials which consist of two soft-smooth, two soft-rough, two hard-smooth and two hard-rough texture stimuli. We presented two materials paired from different texture categories and two sounds created using IPA features obtained from Experiment 1 to Korean native speakers. Then, the participants were asked to judge texture material-sound pairings. As a result, Korean participants have paired smooth-soft materials with smooth-soft sounds and rough-hard materials with rough-hard sounds. The results show significantly more frequent than chance level (binomial test, $p < 0.001$). This result supports our hypothesis that there exists universality of sound-symbolic words expressing visual texture between different linguistic backgrounds.

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43.453 **Interpreting color-coding systems: the effects of concept activation on color inference** Kathleen C. Foley[1,2](kcfoley2@wisc.edu), Laurent Lessard[2,3], Karen B. Schloss[1,2]; [1]Department of Psychology, University of Wisconsin-Madison, [2]Wisconsin Institute for Discovery, University of Wisconsin-Madison, [3]Department of Electrical and Computer Engineering, University of Wisconsin-Madison

People can interpret abstract messages encoded in colors, making color a useful feature for visual communication. Evidence suggests that when people interpret color-coding systems, they infer mappings that maximize the total association strength between colors and their assigned concepts; the assignment hypothesis (Schloss, Lessard, Walmsley, & Foley, 2017). The assignment hypothesis implies that people's interpretations of color-coding systems will vary depending on the degree to which different concepts are activated in their minds while solving color-concept assignment problems. We tested this prediction using a recycling paradigm. Participants saw pairs of different colored bins (unlabeled) and determined which bin was appropriate for discarding different kinds of objects (paper/trash). All participants had at least one kind of object to discard (paper/trash), so that object's concept was highly activated in their minds during the experiment. Across participants, we varied the degree to which a second object was activated. The "one-one" group was told about one object and discarded one object, so the second object was not activated. The "two-one" group was told about both objects, but discarded one object, so the second object was moderately activated. The "two-two" group was told about and discarded both objects, so the second object was strongly activated. We constructed a model to predict how responses would differ across groups if all participants solved an assignment problem to interpret the color-coding system on each trial, but the groups differed in the weight given to the second object (one-one group: weight=0; two-one group: weight=0.5; two-two group: weight=1). The model strongly predicted variations in color selections across groups ($r=0.85$, $p < .001$), suggesting people infer optimal color-concept assignments depending on the input they have. The results emphasize the importance of considering both the colors in the scene and the activated concepts in people's minds for designing intuitive color-coding systems.

Acknowledgement: Wisconsin Alumni Research Foundation

43.454 **What does color sorting tell us about lexical color categorical structure?** Delwin Lindsey[1,2](lindsey.43@osu.edu), Aimee Violette[2], Angela M Brown[2], Prutha Deshpande[1]; [1]Department of Psychology, Ohio State University, [2]College of Optometry, Ohio State University

The striking similarity in basic color naming systems observed worldwide is often attributed to universal biases in the perceptual representation of color (Berlin & Kay, 1969) that guides color lexicon creation and evolution. Using a modified version of Boster's (1986) paradigm for exploring this idea, we asked native English speakers to sort, in separate trials, repre-

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sentative color palettes into n=2...6 piles based on perceptual similarities. In Study I, 45 university undergraduates sorted 145 Munsell chips (5 achromatic, 140 chromatic) that uniformly sampled the variations in hue, chroma and value of the World Color Survey (WCS) chart. Cluster analysis across all n-sorts revealed 15 canonical classification templates, some of which were similar to universal WCS lexical categories, red, green, grue, warm, cool (Lindsey & Brown, 2006). Others, like dark and light, were unlike any universal WCS categories, or those found in English (Lindsey & Brown, 2014). When the classified sorting data were united into color category systems (one for each subject and each n-sort), there were a modest number of motifs that recurred across the n-sorts. Some, but not all, resembled WCS motifs (Lindsey & Brown, 2009). Similar results were obtained in Study II, where a diverse group of 90 adult subjects at our local science museum sorted colors from a palette of 30 representative WCS colors displayed and manipulated on custom-programmed iPads. In Study III, 55 additional subjects sorted 25 test colors varying in hue but similar in Munsell chroma and value. Cluster analysis of Study III revealed 10 canonical classification templates. Some of these resembled universal WCS lexical categories, whereas others resembled minority WCS categories that deviated from predictions of Berlin & Kay's theory. This is interesting because the minority categories come from preindustrial cultures yet are manifest in the n-sorts of technologically modern English speakers.

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43.455 **Tomatoes are red, cucumbers are green: Decoding the temporal dynamics of object-colour knowledge using Magnetoencephalography** Lina Teichmann[1,2](lina.teichmann@students.mq.edu.au), Tijl Grootswagers[1,2,3], Thomas A Carlson[2,3], Anina N Rich[1,2,4]; [1]Perception in Action Research Centre & Department of Cognitive Science, Macquarie University, [2]ARC Centre of Excellence in Cognition & its Disorders, Macquarie University, [3]School of Psychology, University of Sydney, [4]Centre for Elite Performance, Training and Expertise, Macquarie University

Throughout our lives, we accumulate defining perceptual characteristics about objects in our environment, such as their typical colours. There is debate about the degree to which representations of perceptual features involves similar neural mechanisms as perceiving those features. Here, we explore this question using typical colour. Participants completed a target detection task using real and implied colour stimuli. In the real colour condition, we used isoluminant red and green shapes. In the implied colour condition, the stimulus set consisted of grey-scale luminance- and size-matched pictures of fruits and vegetables which are typically red (e.g., tomatoes) or green (e.g., cucumbers). We recorded brain activity using Magnetoencephalography (MEG) and applied Multivariate Pattern Analysis (MVPA) to investigate the temporal dynamics of real and implied colour processing. We show that (1) real colour objects can be reliably classified into red and green categories on the basis of MEG data, (2) trials showing grey-scale pictures of fruits and vegetables can similarly be classified into their natural colour categories, and (3) implied object-colour can be decoded when a classifier is trained on distinguishing real colour, but only with a delay of ~57ms. This delay suggests slower processing of implied colours in comparison to real colours. We tested and confirmed this prediction with a follow-up behavioural experiment, showing that participants are faster at judging whether an abstract shape is red or green than indicating the typical colour of a grey-scale object. Together, these results demonstrate that activating object-colour knowledge and perceiving colour evokes a common brain activation pattern, but that the key difference lies in the time that it takes to access this common colour representation.

43.456 **Isolating perception by fooling cognition: Does color knowledge alter color appearance?** J.J. Valenti[1](jvalen23@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Does a gray banana look yellow? Does a heart look redder than a square? A line of research stretching back nearly a century suggests that knowing an object's canonical color can alter its visual appearance. Are such effects truly perceptual, or might they instead reflect biased responses without altering online color perception? Here, we replicate classical and contemporary "memory-color effects", but then extend them to include conditions with counterintuitive hypotheses that would be difficult for subjects to grasp; across multiple case studies, we find that such conditions eliminate or even reverse memory-color effects in ways unaccounted-for by these theories. We first replicated the classic finding that hearts are judged as redder than squares, as measured by matching a color-adjustable background to a central stimulus. But when we varied the shape of the background itself (to be either square or heart-shaped), subjects who estimated a square's color by adjusting a heart-shaped background adjusted the background to be redder than when adjusting a square-shaped background — whereas a memory-color theory would predict the opposite pattern. Next, we successfully replicated the more recent finding that gray disks and blueish bananas are judged as more purely gray than are gray bananas (which purportedly appear yellow); however, we also found that a blueish disk is judged to be more gray than a blueish banana, exactly opposite the prediction of memory-color theories. Moreover, when asked to identify the "odd color out" from an array of three objects (e.g., gray disk, gray banana, and blueish banana) subjects easily identified the blueish banana as the odd color out, even though memory-color theories predict that subjects should pick the gray banana. We suggest that memory color effects may not be truly perceptual, and we discuss the utility of this general approach for distinguishing perception from cognition.

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43.457 **Paradoxical memory color for faces** Rosa Lafer-Sousa[1](rlaferso@mit.edu), Maryam Hasantash[2], Arash Afraz[3], Bevil R Conway[3,4]; [1]Department of Brain and Cognitive Sciences, MIT, Cambridge MA 02139, [2]Institute for Research in Fundamental Sciences, Iran, [3]National Institute of Mental Health, NIH, [4]National Eye Institute, NIH

We studied the contribution of color to object and face perception by testing memory colors. Twenty participants (10 female) were asked to match colors of real objects, including real human models, under two conditions: white light, and monochromatic sodium light (589 nm) that renders vision objectively achromatic (Boynton & Purl, 1989). Asymmetric color matches (CIE-Lab) were made by adjusting a color-patch on a monitor (visible through an aperture). Prior work on memory color suggests that under objective achromatic conditions, color judgments are biased toward the typical color of objects. Instead, we found that color judgments for most objects reflected only the monochromatic (yellow) bias of the sodium lamp (mean hue angle of non-face object matches, H = 68°; mean error (match – spectral measure) = 2.0°), and did not differ for objects with diagnostic colors (strawberry, orange, tomato) compared to those without (legos, toy phone, ping-pong ball) (p = 0.2). The exception was faces, which appeared green under sodium light (H = 111°; error = 40.3°; p = 6x10-47) for the two races tested (Caucasian, African-American). The effect was abolished when the face context was masked (error = -1.4°; p = 5x10-3), suggesting a systematic interaction of face-shape and color processing. These results provide compelling evidence for perceptual memory color, but they are paradoxical. The memory color was not normal face color, instead it matched unhealthy complexion. Hierarchical clustering analysis revealed that only the recently evolved L-M color channel, not the older S-channel, mediated the paradoxical memory color for faces. This supports the idea that trichromatic vision was selected in primates for its contribution to social communication by encoding chromatic states of the facial skin (Changizi et al., 2006). The paradoxical nature of the memory color reveals a strong prior for face color, triggering an "unnaturalness" error signal when violated by otherwise reliable visual information.

43.458 **Task-dependent biases in a delayed color matching paradigm** Maria Olkkonen[1,2](maria.olkkonen@durham.ac.uk), Toni P Saarela[2]; [1]Department of Psychology, Durham University, [2]Department of Psychology and Logopedics, Faculty of Medicine, University of Helsinki

Both attractive and repulsive biases have been reported in delayed matching paradigms across perceptual domains. Here we ask whether the task structure influences biases in delayed color matching. Methods. Five observers compared the color of stimuli shown briefly in succession across a 1s delay. In a block of trials, five equally spaced reference stimuli covered a 24-degree-wide hue range in CIELAB space. Two different

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hue ranges were used in separate blocks. Two tasks were employed to measure short-term memory biases for color. In the 2IFC task, observers responded whether the second stimulus in a trial (the test) was bluer or yellower than the first stimulus (the reference). 1-up-1-down staircases controlled the test hue. In the modified, delayed match-to-sample task, the first interval contained the reference and the second interval contained two test stimuli. Participants responded which test stimulus appeared more similar in hue to the reference. The hue difference between the two tests was fixed at 6 CIELAB units and both were controlled with a single 1-1 staircase. In both tasks, point of subjective equality for each reference was defined as the average of last five reversals of the staircases. Results. The 2IFC task produced a robust central tendency bias: the reference hues tended to shift towards the mean reference in memory. Surprisingly, there was generally no central tendency bias for the delayed match-to-sample task; in fact, some observers showed a repulsion away from the mean color. Conclusion. Whether observers show attractive or repulsive effects in delayed comparison tasks systematically depends on the task. This difference may arise from the task wording affecting how the stimulus is encoded into memory, any encoding differences being exacerbated by the memory delay.

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43.459 **Noncategorical color perception in multiple object tracking** Mengdan Sun[1](sunmengdan_blcu@163.com), Xuemin Zhang[1,2,3]; [1] Beijing Key Laboratory of Applied Experimental Psychology, National Demonstration Center for Experimental Psychology Education (Beijing Normal University), Faculty of Psychology, Beijing Normal University, [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

Whether or not visual perception is penetrable by high-level cognition has been controversial. Categorical color perception is an example of how cognition modulates perception, which claims that colors across categories (e.g. blue, green) are more discriminable than within category (e.g. green). Most studies on categorical color perception have been conducted in a static visual scene. Here, we investigated the effect of color categories on performance in multiple object tracking (MOT) with two experiments. In MOT, all the targets were assigned a hue varying from blue to green (hue angle: 205° to 170°, step size: 5°) according to condition, while all the distractors were assigned one blue hue (210°) across all conditions. After the MOT task, subjects were required to complete a color naming task to determine the category membership of the stimuli. We fitted the categorization performance with a Sigmoid function and calculated the green-blue border for each subject. The tracking performance was then fitted as a function of the target hue angle. If there was categorical effect, we should expect that the greatest discriminability of the hue angle in MOT would occur around the green-blue border. That is, the hue angle along the tracking curve with the maximum slope should be near the green-blue border. Analysis of correlation between the hue angle with the greatest discriminability in MOT and the green-blue border was then conducted and no significant correlation was found (Experiment 1), including no correlation in the right visual field (Experiment 2). The non-significant correlation suggested that the discriminability of hue differences in MOT is free from the categorization of hues. Yet, Experiment 2 revealed a significant negative correlation in the left visual field, suggesting that color categorization may derive from indiscriminability of chromaticity. Overall, our study supported the noncategorical color perception in MOT.

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43.460 **Effect of imagining another culture on color preference** Erika Kumakura[1,2](kumakura@l.u-tokyo.ac.jp), Annette Werner[1], Kazuhiko Yokosawa[2]; [1]Institute for Ophthalmic Research, Tuebingen University, [2]Graduate School of Humanities and Sociology, The University of Tokyo

Previous studies have reported cultural difference in color preference. For example, Japanese people tend to prefer light colors over muted colors while US people tend to prefer both colors equally (Yokosawa, Schloss, Asano, & Palmer, 2016). What does determine color preference in a certain culture? Ecological Valence (EV) theory (Palmer & Schloss, 2010) expects that color preference is determined by the preference for objects associated with the colors, and implies that different sets of characteristically colored objects will cause cultural diversity in color preference. Extending this implication we ask whether imagination will have a similar effect, i.e., imagining objects/scenes typical of another culture, subjects' color preferences will become similar to color preferences characteristic for that culture. To investigate, we asked German subjects to rate (1) their original color preferences and (2) color preferences while imagining Japanese objects/scenes. In order to allow comparability with other data sets on color preferences, we used the Berkeley Color Project 37 colors applying a standard experimental procedure (Palmer & Schloss, 2010). None of subjects in this experiment stayed in Japan for more than one year. The results show that (1) German color preferences were more strongly correlated with US than with Japanese color preferences, and that (2) the color preferences did indeed change after imagining Japanese objects/scenes; in particular, the preference for light colors became higher than that for muted colors after imagining Japanese objects/scenes, as it is characteristic for Japanese color preferences. The results are consistent with recent findings by Yokosawa et al. (2016) and support the EV theory.

43.461 **Color statistics underlying preference judgement for art paintings** Shigeki Nakauchi[1](nakauchi@tut.jp), Taisei Kondo[1], Hiroshi Higashi[1], João M.M. Linhares[2], Sérgio M.C. Nascimento[2]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Centre of Physics, Campus de Gualtar, University of Minho

Background: It was shown that when observers were asked to rotate the color gamut of images of unfamiliar paintings to select the preferred one, they preferred the color compositions very close to the original paintings (Nascimento et al., 2017; Kondo et al., 2017). This study aims to explore what features of the color compositions underlie such original-preferred judgement for art paintings. Method: 4-AFC paradigm was used to measure the preference for art paintings. Observers (N=52) were asked to select the most preferable one among four images: original (0 deg) and three hue-rotated images (90, 180 and 270 deg) which had the same luminance and mean chromaticity as the original. In addition to the original condition C1, we tested spatial scrambling condition C2 (the images were divided into small square parts and scrambled), mixture condition C3 (the square parts were randomly selected from 20 different images) and hue-randomized condition C4 (the square parts were randomly rotated in hue angle). Results and Discussions: Originals were selected most frequently in C1-3 conditions, suggesting no or little contextual effect on preference. Furthermore, original-preferred judgement even in the mixture condition C3 implies a certain common color structure among art paintings. We therefore analyzed the color statistics in CIELAB of 5,591 art paintings of various categories and found that paintings share the common features regardless of the categories, that is, positive skewness of red-green (a*) and positive correlation between lightness (L*) and blue-yellow (b*). Corresponding to this, regression analysis between preference and color statistics revealed that selection probability of the images measured in the 4-AFC experiment significantly correlated with skewness of a* and correlation between L* and b* of the images. These findings suggest that implicit criteria underlie both in creation and aesthetic judgment of art paintings, probably relating to naturalness and/or novelty of color composition.

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43.462 **Naturalness and aesthetics of colors in the human brain** Sérgio M Nascimento[1](smcn@fisica.uminho.pt), Anke Marit Albers[2], Karl R Gegenfurtner [2]; [1]Centre of Physics, Campus de Gualtar, University of Minho, 4710-057 Braga, Portugal, [2]Justus-Liebig Universität Giessen, Abteilung Allgemeine Psychologie, Giessen, Germany

The colors of paintings and natural scenes are closely related (Montagner et al, 2016, JOSA A). We hypothesized that aesthetic preference for colors might be related to their perceived naturalness and that both judgments might rely on similar brain mechanisms. We asked participants (N=19) to rate images of natural scenes on aesthetic preference and naturalness

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in a psychophysical experiment and while in the fMRI. The degree of naturalness and beauty was manipulated by rotating the color gamut of the images in CIELAB. The images were presented either in their original form or spatially manipulated using a modified version of the 'eidolon factory' (Koenderink et al, 2017, JoV) to remove their semantic content, but preserving the original color statistics. In the behavioral experiment participants performed pairwise comparisons on images of the same scene but with different gamut angles. We obtained individual scaling curves for naturalness and preference as a function of the angle of rotation, using maximum likelihood difference scaling. The naturalness and preference scaling curves were largely similar and their maxima were close to the original image for all conditions and scenes (on average within 20°), suggesting that perception of naturalness and preference are indeed closely related. In the fMRI experiment, the same images were presented one by one in an event-related paradigm and the same participants rated them again for naturalness and preference. We subsequently used the individual scaling curves as parametric regressors to test for brain regions where activity modulated with perceived level of naturalness or preference. Results suggest that unscrambled scenes with natural colors activate the Parahippocampal Place Area more than unscrambled scenes with very unnatural colors. Interestingly, there was also a weak modulation of naturalness close to a region in orbital frontal cortex that has previously been reported to be modulated by preference.

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43.463 **Color categories in aesthetic preferences for paintings** Anke Marit Albers[1](anke-marit.albers@psychol.uni-giessen.de), Florian Schiller[1], Karl R. Gegenfurtner[1], Sérgio M.C. Nascimento[2]; [1]Abteilung Allgemeine Psychologie, Justus-Liebig Universität, Giessen, Germany, [2]Centre of Physics, Campus de Gualtar, University of Minho, 4710-057 Braga, Portugal

Colors influence our perceptual and aesthetic experiences, but their role in the appreciation of paintings is difficult to quantify. A previous experiment showed that observers strongly prefer the color compositions chosen by the artist over color-manipulated versions of the same painting (Nascimento et al, 2017, Vision Research, 130, 76-84). Their manipulation - a rigid rotation of the color gamut around the L* axis in CIELAB space – kept lightness and saturation invariant and therefore preserved the chromatic relationship between the colors. However, it changed perceptual appearance by changing the color spread over color categories. Therefore, we investigated how much this chromatic manipulation affects the distribution of colors over color categories and how it may determine preference scaling of naïve observers. We modeled how the distribution of colors across categories varied with the color-gamut rotation of paintings from various periods and artists. Using hyperspectral imaging data of the paintings, we derived the Euclidean distance in L*u*v* space between each pixel and the most typical color for each color category and assigned each pixel to the closest category. The degree of uniformity across color categories was quantified as the square root of the sum of squared differences between the actual pixel distribution and a uniform distribution, for each painting at each rotation angle. The majority of the paintings had the most homogenous distribution close the original color composition. Interestingly, the orientation of the most homogeneous color distribution was also the one generally preferred by participants (N=14) that performed pair-wise comparison on a subset of the images in a psychophysical study (Albers et al, 2017, ECVP). These results show that the color manipulated versions of the paintings tend to have less uniform color distribution across color categories and suggest that observers may rely on color category diversity in their preference judgments.

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43.464 **The neural substrate for semantic associations underlies color preference judgments** Chris Racey[1,2](c.racey1@gmail.com), Ruyuan Zhang[3], Kendrick Kay[3], Karen B. Schloss[1,2]; [1]Department of Psychology, University of Wisconsin - Madison, [2]Wisconsin Institute for Discovery, University of Wisconsin - Madison, [3]Department of Radiology, University of Minnesota

People form semantic associations with colors, which influence the way they evaluate and interpret the world. Behavioral evidence indicates that evaluations of colors (color preferences) are determined by the combined valence of all entities associated with those colors (Ecological Valence Theory; Palmer & Schloss, 2010; Schloss & Palmer, 2017). This implies that when people judge their preference for a color, semantic associates of that color are activated, and then the valences of those associates are pooled to produce the color preference response. Therefore, we predicted that brain areas involved in visual semantic processing (perirhinal cortex (PrC) in the anterior temporal lobe; Martin et al., 2017) would be recruited during color preference judgments and object association judgments, but not during perceptual judgments. We tested these predictions in a high-field fMRI study (7T, 2 mm, 1.2 s) in which naive participants ($n = 10$) viewed a set of calibrated color patches while performing four different tasks. We anatomically defined PrC in each subject using established criteria (Pruessner et al., 2002) and used a general linear model to estimate BOLD responses. We found that the BOLD signal in PrC remained at baseline when participants performed a fixation task ignoring the color patches ($p > .05$) as well as when participants judged the lightness of the color patches ($p > .05$). However, the BOLD signal in PrC increased when participants judged their preference for the colors ($p < .05$) and when participants explicitly associated objects with the colors ($p < .05$). Therefore, the neural substrate involved in semantic processing underlies color preference judgments, but not perceptual judgments about the same stimuli. These results provide the first evidence of a neural instantiation of the Ecological Valence Theory for color preferences, and highlight the rich diversity of neural responses that can be elicited by cognitive judgments made on simple sensory stimuli.

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43.465 **Human V4 Activity Patterns Predict Behavioral Performance in Imagery of Object Color** Michael M Bannert[1,2,3,4](m-bannert@tuebingen.mpg.de), Andreas Bartels[1,2,3,4]; [1]Werner Reichardt Centre for Integrative Neuroscience, University of Tübingen, [2]Bernstein Center for Computational Neuroscience, [3]Max Planck Institute for Biological Cybernetics, [4]Department of Psychology, University of Tübingen

Among the multitude of elements making up visual experience, color stands out in that it can specify both subjective experience and objective properties of the outside world. Whereas most neuroimaging research on human color vision has focused on external stimulation, the present study addressed this duality by investigating how externally elicited color vision is linked to subjective color experience induced by object imagery. We recorded fMRI activity while showing our participants abstract color stimuli that were either red, green, or yellow in half of the runs ("real-color runs") and asked them to produce mental images of colored objects corresponding to the same three categories in the remaining half ("imagery runs"). To make sure that participants were engaged in visual imagery, they performed a 1-back same/different color judgment task on the imagined objects. We trained color classifiers using MVPA to distinguish between fMRI responses to the three color stimuli and cross-validated them on data from real-color or imagery runs. Although real-color percepts could be predicted from all retinotopically mapped visual areas, only color decoders trained on hV4 responses could additionally predict the color category of an object that was being imagined. This suggests that sensory-driven and self-induced colors share a common neural code in hV4. Using a hierarchical drift diffusion model, we furthermore demonstrated that the decoding accuracy in hV4 was predictive of performance in the color judgment task on a trial-by-trial basis. The commonality between neural representations of perceived and imagined object color, in combination with the behavioral modeling evidence, hence identifies area hV4 as a "perceptual bridge" linking externally triggered color vision with color in self-generated object imagery.

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43.466 Identifying multivariate patterns for illusory color perception using decoded fMRI neurofeedback JD Knotts[1,2](jeffreydknotts@gmail.com), Aurelio Cortese[1], Mitsuo Kawato[1,4], Hakwan Lau[1,2,3,4]; [1]Department of Decoded Neurofeedback, ATR Computational Neuroscience Laboratories, [2]Department of Psychology, University of California, Los Angeles, [3]Brain Research Institute, University of California, Los Angeles, [4]Faculty of Information Science, Nara Institute of Science and Technology

Previous studies have shown that spontaneous fluctuations in prestimulus fMRI activity can predict trial-by-trial fluctuations in the perception of identical stimuli (Boly et al., 2007; Hesselmann et al., 2008, 2010; Sadaghiani et al., 2009; Rahnev et al., 2012; Pajani et al., 2015), yet such activity on its own does not seem to lead to conscious perception, even when awareness is carefully assessed in a forced-choice manner (Shibata et al., 2011; Amano et al., 2016). Here, we investigated why awareness is lacking in these cases, and whether it may be possible to make spontaneous activity conscious. We hypothesized that for consciousness to arise, specific neural patterns in both visual and frontoparietal areas may be required. To encourage the co-occurrence of such activity, we used MVPA-based decoded fMRI neurofeedback (DecNef) (Shibata et al., 2011). In previous work we identified frontoparietal voxel patterns representing high perceptual confidence (Cortese et al., 2016). Here, we rewarded subjects for simultaneously inducing these patterns for high perceptual confidence in frontoparietal areas and specific patterns for color in visual areas. We found that false color perception was associated with activation of high confidence patterns in frontoparietal areas, but not with activation of color patterns in visual areas. This suggests a unique role for a frontoparietal network in the promotion of spontaneous neural representations from an unconscious to a conscious state.

Acknowledgement: NSF Graduate Research Fellowship

Eye Movements: Pupil and melanopsin

Monday, May 21, 8:30 am - 12:30 pm

Poster Session, Pavilion

43.467 Longitudinal study of relationships between psychomotor vigilance, tonic and phasic pupil responses, and natural sleep history across 16 weeks Steven M Thurman[1](steven.matthew.thurman@gmail.com), Nick Wasylyshyn[1], Javier O Garcia[1], Gold Okafor[2], James Elliott[2], Barry Giesbrecht[2], Scott Grafton[2], Erin Flynn-Evans[3], Jean M Vettel[1]; [1]Human Research and Engineering Directorate, US Army Research Laboratory, [2]Department of Psychology, UC Santa Barbara, [3]Human Systems Integration Division, NASA Ames Research Center

Performance in a cognitive task domain can fluctuate broadly within an individual over time, often in relation to intrinsic neurophysiological states that change on various timescales. For example, attention and arousal can impact task performance on a relatively short timescale, but neurophysiological effects from chronic sleep loss and fatigue likely influence behavior and performance on a much broader timescale. We conducted a longitudinal 16 week study in which participants (n=15) returned biweekly (8 sessions) to perform a psychomotor vigilance task (PVT) with eye-tracking to investigate relationships between pupil diameter (tonic baseline and phasic event-related responses) and performance variables (response speed, lapse rate). Across the study period, we monitored naturalistic sleep patterns with daily sleep diaries and wrist actigraphy (Readiband SBV3) to estimate objective fatigue via effectiveness score using Sleep, Activity, Fatigue, and Task Effectiveness "SAFTE" model (Hursh et al., 2004). We examined pupillary predictors of fluctuations in biweekly performance, using correlation coefficients and linear mixed models to examine between-subjects and within-subjects effects. We found that within-subject variability of response speed and lapse rate across sessions was significantly associated with changes in both tonic and phasic features of pupil diameter. Experimental sessions showing a relatively faster mean response speed and correspondingly lower lapse rate (relative to the individual's mean) were associated with larger tonic pupil diameter, lower peak amplitude, and shorter latency of the mean phasic response. We used multivariate models to examine the influence of several sleep and fatigue-related variables on task performance. Within subjects, we found that lower effectiveness score (higher fatigue) was associated with slower response speed, higher lapse rate, and smaller tonic pupil diameter. These results reveal long-timescale relationships within individuals between the pupillary system and vigilance-related performance outcomes, with a modulating influence from natural variability in states related to sleep and fatigue.

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43.468 Association between pupil constriction and aesthetic preference/naturalness in art-paintings Yuma Taniyama[1](taniyama17@vpac.cs.tut.ac.jp), Yuta Suzuki[1], Taisei Kondo[1], Tetsuto Minami[1], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, Japan

Background: Pupil dilation was shown to reflect the extent of preference in Mondrian painting (Johnson et al., 2010). Objective of this study is to investigate whether the pupillary response reflects aesthetic preference/naturalness in art-paintings (Kondo et al., 2017). Method: All paintings used as the stimulus were selected from WikiArt and categorized into "Abstract", "Flower" and "Poster". Observers were presented either original paintings or hue-flipped ones (180 deg rotated in hue angle). Pupil size was recorded monocularly with EyeLink 1000+ (SR Research, Mississauga, ON, Canada) while presentation of paintings. The preference and naturalness for art-paintings were evaluated subjectively by asking observers to rate preference and naturalness with trackball mouse. 18 observers participated in the experiment. Results and Discussions: In all paintings, observers' pupil constriction rate increased while they viewed hue-flipped paintings compared to the original paintings. In addition, original paintings were preferred and perceived more natural compared to hue-flipped paintings. Moreover, significant correlation was found between preference and naturalness. Hence, we performed a regression analysis to examine the relationship between pupil response and other factors (preference, naturalness and lightness (L* in CIELAB)) in each category. For all paintings categories, pupil constriction was influenced by subjective preference and naturalness. However, the results indicated that mean lightness (L*) was effective only in the category "Poster". In other words, pupil was largely influenced by preference and naturalness rather than lightness (L*) in "Abstract" and "Flower" paintings, suggesting that it is possible to evaluate subjective preference and naturalness by pupil response not just for realistic paintings such as "Flower" but also for abstract paintings.

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43.469 The effect of changes in screen luminance and lighting on pupillary response during web-surfing Evgeni Shelepin[1](sey2@ya.ru), Katerina Malakhova[1]; [1]Pavlov Institute of Physiology Russian Academy of Sciences

Most of eye-tracking devices provide information not only about gaze location but also pupil size, which is not commonly used. Pupil dilation is known as indicative factor for cognitive load, memory operations, emotions, involvement, anticipation of the rivalry switch, pain. The reflection of mental processes in pupil size make the latter a good psychophysical metric, which can be measured distantly. However, pupil changes are also affected by amount of light, perceived by the eyes, also called light reflex. The balance between mental factors and light level and it's influence on pupil size is still a matter of discuss. In this paper, we used our eye-tracking dataset to check correlation between pupil size and luminosity level. Dataset represents the data of users performing everyday activities, such as web browsing, video watching, reading, social networking. It contains 19 hours of simultaneous recording of webcam, screen and eye-tracking data of 32 users. For each screen video frame was calculated average screen brightness (luminance). Then, smoothing and filtering methods we used to reduce eye-tracker noise. To estimate the effect of luminance changes on pupil size we apply time series analysis. The results show moderate correlation between PD and screen luminance and no correlation between PD and webcam frame luminance. However, the analysis of PD dynamics shows strong delayed response to changes in both lighting and screen luminance, which reaches its maximum in about 1 second after the change. The observed delay in pupil response should be taken into account in experiments where pupil size serves as an indicator

of mental processes. Despite weak or zero correlation between current environment luminance and PD, changes in luminance have prolongated impact on dynamics of pupillary response.

43.470 **The differential effect of glowing appearance in the glare illusion: evidence from pupillometry** Yuta Suzuki[1](suzuki14@vpac.cs.tut.ac.jp), Tetsuto Minami[1,2], Bruno Laeng[3], Shigeki Nakauchi[1]; [1]Department of Computer Science and Engineering, Toyohashi University of Technology, [2]Electronics-Inspired Interdisciplinary Research Institute, Toyohashi University of Technology, [3]Department of Psychology, University of Oslo

The glare illusion is a pictorial representation where one perceives self-luminosity in the absence of physical luminance. Several pupillometry studies have investigated such illusory brightness enhancement in terms of automatic, physiological, responses and shown that the enhanced brightness perception can be reflected in pupil constrictions to the illusory light, despite there is no corresponding physical luminance change. However, an illusory brightness enhancement occurs also with ''white'' or "gray'' patches in the central region of the glare illusion and not only in the perceptual mode of ''self-luminosity'' (Tamura et al., 2017). Thus, we aimed to explore what factor contributes to the pupil constriction according to these two aspects of illusory perception with a pupillometry experiment where participants observed either as a colored glare illusion, which had color-inducer in the peripheral gradient region, or as a control condition which inverted the gradients, so as to manipulate the perceived brightness while keeping equiluminance across conditions (Experiment1a). We confirmed the presence of brightness enhancement, dependent on the color-inducer, using a method of adjustment (Experiment1b). Although the amount of pupil constriction was significantly correlated with the perceived brightness in each colored glare illusion, the differences in pupil constrictions between glare and control stimuli were similar across the color conditions (n=16). Subsequently, we also conducted an experiment probing the level of luminosity perception, by using glare illusions with varied angle of the gradients to affect the participants' perceptual mode from 'white' to 'luminous' (Experiment2). The results showed that pupillary constriction was increased only when the participants reported a feeling of luminosity from the glare illusion (n=13). These findings suggest that although the pupillary constriction indeed reflects enhanced brightness of the glare illusion, it does also reflect a perceptual mode of luminosity.

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43.471 **Does the spectral sensitivity of melanopsin in ipRGCs suggest a role in chromatic adaptation?** Daniel Garside[1](danny-garside@outlook.com), Lindsay MacDonald[1], Kees Teunissen[2]; [1]CEGE, UCL, [2]Philips Lighting Research

A computational approach was used to examine whether the spectral sensitivity of melanopsin, the light sensitive protein in the intrinsically photosensitive retinal ganglion cells (ipRGCs), could play a role in chromatic adaptation by providing a calibration signal to correct for daylight variability. Estimates of the signals generated with the spectral sensitivities for each cone type, short (S), medium (M) and long (L), and for melanopsin expressing cells, for a range of objects (both natural and non-natural), under a range of daylight illuminations, were computed from existing datasets. The predictive power of any individual photoreceptor type to influence chromaticity was determined, and found to be essentially non-existent. Signals derived from combinations of more than one photoreceptor type were then considered for suitability. Signals derived solely from combinations of cone-based signals were found to have inherent correlations to chromaticity, representing spurious relationships following from the fact that chromaticity is defined in this same way. These signals were thus considered to be of little value as calibration signals. Signals derived from combinations of melanopic and cone-based signals were at least as effective in predicting chromaticity as signals derived solely from cone-based signals. It was found that one combination of a melanopic signal with a luminance-like signal, when applied with appropriate weighting to the chromaticity values for an object, successfully reduces the variance between the chromaticities of that object under different illuminants. Variations on the spectral sensitivity of melanopsin were considered, by shifting the peak of the melanopsin sensitivity function, to investigate whether the recognised spectral sensitivity of melanopsin was uniquely effective in this task. The results suggest an approach to constructing a model of visual response that incorporates a melanopic input to modify L,M,S cone signals to compensate for changes in the spectrum of the ambient daylight illumination.

Acknowledgement: EPSRC/Philips

43.472 **The population mean pupil response to melanopsin stimulation is reliable across sessions and background light levels** Harrison M McAdams[1](harrison.mcadams@gmail.com), Aleksandra Igdalova[1], Manuel Spitschan[2], David H Brainard[2], Geoffrey K Aguirre[1]; [1]Department of Neurology, Perelman School of Medicine, University of Pennsylvania, [2]Department of Psychology, University of Pennsylvania

We examined if the pupil response to melanopsin stimulation differs from that to cone stimulation, and if these pupil responses are stable in a healthy population. Following a pre-registered protocol (https://osf.io/76u9x/), we measured the pupil response to 3-second unipolar spectral pulses in each of 24 people during two separate sessions. These were designed to selectively stimulate either melanopsin (Mel) or the L, M, and S cones (LMS). The pulses produced 400% nominal contrast upon the targeted retinal mechanism and were presented against a rod-saturating background (~100 cd/m2 for Mel, ~40 cd/m2 for LMS). The group average shape of pupil constriction expressed as percentage change from baseline for each stimulus was highly consistent from the first to second session, suggesting that the pupil response is reproducible in a healthy population (Mel r = 0.995; LMS r = 0.999). We quantified the temporal dynamics of the pupil response. This revealed that the pupil response to Mel stimulation was prolonged relative to that of LMS stimulation. 21 subjects underwent a third pupillography session identical in structure to the first two except at higher light levels (background luminance for Mel and LMS pulses were increased to ~270 and ~100 cd/m2 respectively). The shape of the group average response (expressed in percentage change) to Mel and LMS stimulation was again highly overlapping with the responses from the first two sessions (Mel r = 0.994; LMS r = 0.999), suggesting that these pupil responses are independent of background light level. We find the pupil response to selective melanopsin stimulation is highly stable in a healthy population, and that the temporal dynamics of the Mel-driven response differ from those of the LMS-driven response. This high degree of reproducibility suggests that tests for clinical differences in response will be well powered with a reasonable number of subjects.

43.473 **Binocular Summation in the Melanopsin Pathway in Visually Normal Observers** Marija Zivcevska[1](marija.zivcevska@mail.utoronto.ca), Al Blakeman[4], Shaobo Lei[3], Xingqiao Chen[4], Herbert C. Goltz[1,3,4], Agnes M.F. Wong[1,2,3,4]; [1]Neurosciences and Mental Health, The Hospital for Sick Children , [2]Ophthalmology and Vision Sciences, The Hospital for Sick Children, [3]Ophthalmology and Vision Sciences, University of Toronto, [4]The Krembil Research Institute, Toronto Western Hospital

Introduction: The development of chromatic pupillometry has propelled significant advances in knowledge of the melanopsin-containing intrinsically photosensitive retinal ganglion cell (ipRGC) light detection pathway. Studies have used open-loop (stimulation of dilated eye and recording from fellow eye) and closed-loop (stimulation and recording of same eye) monocular paradigms to investigate pupil response dynamics; however it is not clear how intrinsic ipRGC signals from the two eyes are integrated. We investigated the binocular summation properties of the melanopsin-derived ipRGC signals using chromatic pupillometry. If the melanopsin system is summative, we hypothesized that there will be greater post-illumination pupillary response (PIPR) under binocular conditions when viewing melanopsin-active bright blue light. Methods: Pupillary responses were recorded with an eye tracker in 10 visually-normal participants. PIPR(10-25s post-illumination) was induced with full-field melanopsin-active blue light (470nm) and melanopsin-silent red light (635nm) stimuli at 60 cd/m2, presented for 400 ms with a Ganzfeld screen. Individual monocular responses were measured first (closed-loop paradigm) followed by binocular responses, 3 times on 3 separate days. To account for individual variability in pupil diameter, the pupil data was normalized to a 5s period before each stimulus (normalized pupil diameter = absolute

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pupil diameter/baseline pupil diameter). Results: Under blue light stimulation, PIPR responses were significantly greater for binocular than monocular viewing ($p < 0.001$), with a mean normalized difference of 0.13 (95% CI, 0.1-0.16), between viewing conditions. There was also a small but significant difference in PIPR between viewing conditions under red light stimulation ($p = 0.01$), with a mean normalized difference of 0.03 (95% CI, 0.01-0.05) between viewing conditions. Overall no effect of viewing eye was found on monocular trials. Conclusion: Melanopsin-mediated ipRGC signals are summated binocularly upstream of the retina. This evidence can be utilized to refine future protocols that target clinical populations, particularly those involving asymmetric ocular neuropathy.

43.474 **Effect of background melanopsin activation levels on contrast sensitivity mediated by postreceptoral pathways** Michael R Tan[1](mtan30@uic.edu), Clemente Paz-Filgueira[1], Pablo Barrionuevo[2], Dingcai Cao[1]; [1]Department of Ophthalmology and Visual Sciences, University of Illinois at Chicago, Chicago, IL USA, [2]Instituto de Investigación en Luz, Ambiente y Visión, Consejo Nacional de Investigaciones Científicas y Técnicas, Tucumán, Argentina

Introduction: Intrinsically photosensitive retinal ganglion cells (ipRGCs) are sensitive to light through a photopigment called melanopsin. IpRGCs project axons to the lateral geniculate nucleus, suggesting melanopsin activation may contribute to visual perception. Here, we assessed the effect of background melanopsin activation level on contrast sensitivity mediated by the magno- (MC-), parvo- (PC-) and konio-cellular (KC-) pathways. Methods: A Maxwellian-view 5-primary photostimulator that can independently control rods, three types of cones and melanopsin activation in ipRGCs was used to generate square-wave modulations (1, 3, 8 and 16 Hz) targeting the three visual pathways, including L+M+S for the magno-, L/(L+M) for parvo- and S for konio-cellular pathway. The stimulus field was a 10.5°-30° annulus. For each stimulus type, temporal contrast sensitivity was measured 2,000 and 20,000 Td under two background melanopsin activation conditions, “Mel-High” and “Mel-Low”, with the “Mel-High” condition having background melanopsin activation 25.6% higher than the “Mel-Low” condition. Results: At 20,000 Td, a higher background melanopsin level decreased contrast sensitivity at most of the test frequencies for the modulation types. At 2,000 Td, however, contrast sensitivity was reduced only at 8 Hz and 16 Hz for the S/(L+M) modulation in the KC-pathway. Conclusions: Background melanopsin activation level can modulate the contrast sensitivity mediated by the MC-, PC- and KC-pathways, and the melanopsin´s modulation effect depended on light levels

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Monday AM

Tuesday Morning Talks

Visual Memory: Encoding and recall

Tuesday, May 22, 8:15 - 9:45 am, Talk Room 1

Moderator: Stefanie Becker

51.11, 8:15 am **Stimuli are encoded relationally, not independently in visual short-term memory** Aimee Martin[1](aimee.martin@uqconnect.edu.au), Stefanie I Becker[1]; [1]The University of Queensland

Visual short-term memory (VSTM) is a vital cognitive resource that allows storing visual information over short time periods. Current theories postulate that stimuli are encoded and stored individually in VSTM. However, studies on the relational account of attention have shown that stimuli are often encoded in a relational, context-dependent manner (e.g., as larger, redder, darker), and it is well-known that attention is closely linked to VSTM. The present study critically tests whether the relational account of attention can be extended to VSTM, viz., whether stimuli are also stored in a context-dependent manner in VSTM. In a change detection task, we used a range of similar colours (green to blue, yellow to red, etc.) and compared performance when a stimulus changed such as to retain its relative colour (e.g., the reddest item changed to a different shade of red, whilst still being the reddest item in the test display) versus when it evoked a relational change (e.g., the reddest item changed such that another item became the reddest item). Although the magnitude of the colour change was the same in both conditions, participants were significantly more likely to notice the change when the relative colour of the item changed than when it remained the same, indicating that information about relative colours was stored in VSTM. In a second experiment, we compared the CDA component in the EEG of participants to determine whether the CDA is sensitive to feature relationships. Preliminary results show that the CDA was smaller when displays allowed storing information in terms of simple feature relationships (rather than, e.g., encoding and storing dissimilar colours). Collectively, these results suggest that elementary features such as colours are encoded and stored in VSTM in a relational, context-dependent manner, rather than individually and independently.

51.12, 8:30 am **Preexisting spatial biases influence the encoding of information into visual working memory** Colin Quirk[1,2](cquirk@uchicago.edu), Kirsten Adam[1,2], Edward Vogel[1,2]; [1]Department of Psychology, University of Chicago, [2]Institute for Mind and Biology, University of Chicago

The sharp limit of working memory necessitates the selection of a subset of items from large memory displays to keep capacity from being overloaded. Because each item in the display is equally likely to be tested, this process is assumed to select items randomly from the entire array. However, the presence of grouping cues substantially impacts which items will be selected for storage, even when they are no more likely to be tested than ungrouped items (Woodman et al., 2003). Furthermore, performance for specific configurations of arrays is consistent across participants (Brady & Tenenbaum, 2013), suggesting that similar information tends to be encoded from each display. Here, we tested the hypothesis that participants have a preexisting spatial bias that prioritizes the selection of items in certain portions of the visual field. Analyzing a large dataset of change detection performance (N=271) revealed that changes in the upper left quadrant were detected much more frequently than changes in the bottom right, suggesting that items in the upper left were preferentially encoded into memory. We examined the impact of these spatial biases in a new experiment in which we manipulated the probability of changes in each quadrant, which has been shown previously to bias selection towards those items (Umemoto et al., 2010). Participants (N=28) were unknowingly assigned a dominant quadrant where 80% of all changes occurred. Accuracy dramatically improved for detecting changes in the dominant quadrant over the nondominant quadrants, with one exception: participants assigned to the bottom right condition showed no improvement in that quadrant and continued to show superior performance in all other quadrants. These results suggest that individuals have strong preexisting spatial biases that affect the encoding of information into working memory and that the lower right quadrant may be a "blind spot" for selection within crowded displays.

51.13, 8:45 am **The Effects of Prior Stimulus Familiarity on Visual Working Memory Maintenance and Retrieval** Weiwei Zhang[1](weiwei.zhang@ucr.edu), WeiZhen Xie[1]; [1]Dept. of Psychology, UC Riverside

We previously demonstrated that stimulus familiarity could speed up Visual Working Memory (VWM) consolidation, which can subsequently manifest as an increase in the amount of information that can be retained in VWM if VWM consolidation is incomplete. The present study further assesses whether this familiarity-related advantage in VWM processing can also manifest to VWM maintenance and retrieval. Experiment 1 manipulated retention intervals of a change detection task for Pokémon characters. Consistent with some previous findings, a larger number of representations was retained in VWM for familiar Pokémon characters than unfamiliar Pokémon characters. However, this effect only manifested at a short (1.5 second) delay interval, and disappeared at a longer (5.5 second) delay interval. The absence of the familiarity effect at the longer delay was unlikely due to decreased task performance, since the familiarity effect remained when task performance was interrupted by masking stimuli presented during the short delay interval. These findings suggest that the improvement in VWM storage by prior familiarity is robust but short-lived in that it can survive interference, but not time. Experiment 2 tested whether prior familiarity also improved VWM retrieval using Event-Related Potentials elicited by the test array of the change detection task for Pokémon. As compared to unfamiliar Pokémon, memory representations for familiar Pokémon elicited larger P1, indicating that familiar information in VWM can be accessed more efficiently. Together, these findings illustrated various sources for the facilitation of VWM by prior stimulus familiarity and highlighted the pivotal roles of VWM processes in the interactions between prior knowledge in long-term memory and moment-by-moment processing of retained information in working memory.

51.14, 9:00 am **Visual recall memory contains highly detailed and precise object and spatial information** Wilma A Bainbridge[1](wilma.bainbridge@nih.gov), Elizabeth H Hall[1], Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health

While there has been much research investigating visual recognition memory, little work has examined the specific content of visual free recall memory, despite evidence that these may be two neurally distinct processes. Here, we quantify the capacity and resolution of visual free recall for complex real-world scene images using a drawing task. Participants (N=30) studied 30 real-world scenes (10s each) and after an 11-min digit span distractor task, drew as many images as possible from memory in as much detail as possible. To serve as benchmarks, separate participants made 1) drawings from the scene category names ("lower bound"), reflecting canonical representations of a scene, and 2) drawings created while looking at the image ("upper bound"), reflecting the maximum information that could be drawn. We leveraged online crowd-sourced experiments on Amazon Mechanical Turk to objectively score the content of these 1,782 drawings. These ratings revealed an impressive detail contained in peoples' memories. First, memory drawings were easily matched to their corresponding image, and were nearly as diagnostic as those drawn directly from the image. Second, memory drawings contained 73.9% of the objects in the drawings made directly from the image, and on average, participants recalled 151.3 objects across the experiment with very few false alarms (1.83 objects across the experiment). Third, the spatial arrangement of objects in memory drawings was highly accurate, and almost identical to the original image. Further, computer vision graph-based visual saliency maps significantly predicted which

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objects would be remembered by participants. Collectively these results suggest that visual recall memory contains diagnostic, detailed, and precise representations of real-world scenes.

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51.15, 9:15 am **Neural Tuning Curves in Visual Working Memory** Chunyue Teng[1](cyteng@gwmail.gwu.edu), Dwight J. Kravitz[1]; [1]Department of Psychology, The George Washington University

The sensorimotor recruitment model proposes that information in visual working memory (VWM) is maintained in posterior visual areas (e.g. D'Esposito & Postle, 2015). This model has found support in recent neuro-imaging studies demonstrating decoding of VWM content in the posterior sensory cortices. However, there has been little behavioral evidence to support this model. Here, we hypothesized that if VWM storage takes place in visual cortices, the effectiveness of an interfering stimulus on the memory representation depends on the similarity of the population response across neurons in these areas. For example, decoding of the orientation of gabor patches in VWM has been reported in early vision cortex (Harrison & Tong, 2009), wherein neuronal populations are tuned for specific orientations. The more similar an interfering stimulus to the memory item along the dimension which defines that tuning, the more overlap in neuronal responses and the more interference. To investigate this hypothesis, we had participants memorize either an oriented gabor, color patch, or motion direction and then perform an orthogonal task between study and report. During this orthogonal task, an unrelated distractor was presented which varied systematically in similarity to the remembered stimulus along the relevant dimensions. In every case we found a monotonic relationship between similarity and the effectiveness of the distractor as measured by 1) the degree to which it biased the report towards itself and 2) the precision/certainty/stability of the resulting VWM representation as measured by the variability in the report. Thus, more similar distractors more strongly affected VWM representations as predicted by the tuning curves of present in perceptual cortices. These results strongly support the sensorimotor recruitment model and suggest a novel behavioral method for investigating the content and nature of VWM representations in the perceptual cortices.

51.16, 9:30 am **Swap Errors in Spatial Working Memory are Informed Guesses, Not Binding Errors** Michael S Pratte[1](prattems@gmail.com); [1]Mississippi State University

In a typical visual working memory task participants study an array of colored items and must report the color of an item at some probed location. In some recent studies, however, a color is probed and participants must report the location of that item. A striking difference between these tasks is a preponderance of so called "swap errors" in location reports, whereby participants almost never guess randomly as they do when reporting color, but instead mistakenly report the location of non-probed items. This finding has been taken as evidence for feature binding errors in memory, and evidence against the prediction of discrete capacity models that guessing should occur at high set sizes. We propose an alternative interpretation: That "swap errors" in location memory are in fact random guesses, but smart ones. In particular, when asked to report the location of a color for which participants have no memory, they may guess at locations where they know some item was presented, and avoid guessing at locations where they know no items were presented. In Experiment 1 we find evidence of such informed guessing by examining confidence ratings: When participants respond near non-studied items they have low confidence, indicating guessing rather than a true swapping of colors and locations in memory. In Experiment 2 we asked participants to report the locations of colors that were not in the study array. The errors and confidence ratings on these false-probe trials look exactly like swap errors — reports are centered around non-studied items and confidence is low — even though there was no studied item that could have possibly been swapped. These results suggest that the tendency to report features of non-probed items reflects a good guessing strategy; not something fundamental about how features and objects are represented in working memory.

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Color and Light: Higher level

Tuesday, May 22, 8:15 - 9:45 am, Talk Room 2

Moderator: Anya Hurlbert

51.21, 8:15 am **Effects of illumination on the perceptual categorization of surface materials** Farley Norman[1](Farley.Norman@wku.edu), James T. Todd[2]; [1]Psychological Sciences Department, Ogden College of Science and Engineering, Western Kentucky University, [2]Psychology Department, The Ohio State University

An important problem in the study of human perception is to understand how it is possible to identify different types of surface materials. One factor that complicates this issue is that materials can be observed with many different patterns of illumination. The present research was designed to examine how this affects the abilities of observers to categorize metal, shiny black materials and shiny white materials. The stimuli depicted three possible objects that were illuminated by five possible HDRI light maps. These light maps were chosen so that they varied significantly in the overall range of illuminant directions, and their intensities were also systematically manipulated. The surfaces included a low roughness chrome material, a shiny black plastic material, and a shiny white plastic material with both diffuse and specular components. Observers rated each stimulus by adjusting four sliders to indicate their confidence that the depicted material was metal, shiny black, shiny white or something else, and these adjustments were constrained so that the sum of all four settings was always 100%. The results revealed that these categories are easily confused. For example, metal materials with low intensity light maps or a narrow range of illuminant directions are often judged as black plastic. Similarly, black plastic materials with high intensity light maps or a very wide range of illuminant directions are often judged as white plastic or metal. In an effort to explain these results, we propose that the perceptual categorization of shiny materials is heavily influenced by image contrast and the overall proportion of a visible surface that is covered by specular highlights.

51.22, 8:30 am **Distinguishing Glossy from Matte Textured Materials** Konrad E Prokott[1](eugenprokott@hotmail.com), Hideki Tamura[2], Roland W Fleming[1]; [1]Justus-Liebig-Universität Giessen, [2]Toyohashi University of Technology

Humans readily distinguish between matte and glossy surfaces, but the underlying visual computations remain poorly understood. Here, we took a data-driven approach to identifying gloss cues, by learning from large numbers of images. We created 75,000 scenes with varying objects, light-probes and viewpoints, each rendered once with a high gloss (mirror-like) material and once with a low gloss (near-matte) material. Texture patterns on the low gloss surfaces ensured that contrast and saturation alone could not distinguish the two classes. 10 participants classified 300 such images as either glossy or matte, achieving 79-93% correct. We then trained a series of classifiers to distinguish the two materials: linear classifiers trained on simple intensity and colour statistics and Portilla-Simoncelli texture statistics, as well as convolutional neural networks (CNNs) with different architectures. For randomly selected renderings, all classifiers correlated very well with humans. However, this was likely due to the high accuracy of both human and model classifiers. We therefore tested observers on further images until we had assembled a 'difficult' test set spanning the range from consistently correctly to consistently incorrectly judged images. For all classifiers, correlations with human judgments dropped precipitously for the difficult set. Using Bayesian hyper-parameter search we then identified CNN architectures that, when trained on the standard renderings, also correlated highest with humans on the difficult test set (not used for training). Finally, we trained Generative Adversarial Networks of varying depths to create images of the two material categories. We tested these images on human observers to arrive at a network depth that is sufficient to imitate those features that humans use to distinguish between high gloss and low gloss textured materials. There are striking similarities between these networks and the CNNs that could predict human judgments.

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51.23, 8:45 am **Illusory transparency and optical blur induced by single shaded surfaces** Scott W.J. Mooney[1](swj.mooney@gmail.com), Barton L. Anderson[2]; [1]Burke Medical Research Institute, Weill Cornell Medicine, [2]University of Sydney

A large body of research has investigated the visual system's ability to disentangle 3D surface shape, material, and illumination from ambiguous image gradients, but less is known about how surface features are distinguished from optical defocus. Defocused surfaces can generate gradients that closely resemble the low spatial frequency shading patterns generated by fully focused, smoothly curved matte surfaces. We previously showed that the visual system misinterprets fully focused shaded surfaces as blurred in the absence of sharp bounding contours. Here, we report a surprising new form of illusory transparency induced by coherent, rendered surfaces. When low frequency surface relief and high frequency surface relief are combined into a single surface, they appear as two distinct layers, and the low frequency component continues to appear blurred. We sought to determine what form of texture is needed to generate a percept of a coherent, single surface and eliminate this illusory blur. We synthesized stochastic surface relief such that it would produce images with a 1/f amplitude spectrum, then introduced a 'gap' of varying width in the middle bands of frequencies used to construct the surface's texture. When the gap was sufficiently large, the low and high frequency components appeared to split into two superimposed layers. The perception of a coherent surface was lost when the gap's bandwidth was greater than approximately one octave, consistent with experiments using simple luminance gratings (Stromeyer & Klein, 1975). These results suggest that discontinuous gradients in the frequency domain are experienced as two distinct generative sources, even when produced by a single realistic surface. Our findings further demonstrate that the illusory blur induced by low frequency shaded surfaces can only be eliminated with textures that produce images exhibiting a continuous band of frequencies, which reflects the self-similar structure of the fractal textures that populate our natural environment.

51.24, 9:00 am **Reconstructing subjective color experiences across the human visual hierarchy** Insub Kim[1,2](insekim@gmail.com), Sang Wook Hong[3,4], Steven K. Shevell[5,6], Won Mok Shim[1,2]; [1]Center for Neuroscience Imaging Research, Institute for Basic Science (IBS), [2]Department of Biomedical Engineering, Sungkyunkwan University (SKKU), [3]Department of Psychology, Florida Atlantic University, [4]Center for Complex Systems and Brain Sciences, Florida Atlantic University, [5]Department of Psychology, Department of Ophthalmology & Visual Science, The University of Chicago, [6]Institute for Mind and Biology, The University of Chicago

The colors we experience are mental percepts. Light of a certain wavelength enters the eye, resulting in a neural representation of the retinal stimulus, but the hues we see depend on higher-level neural signals that cause our visual percepts. Whether the neural representation of chromatic information at each stage of the human visual hierarchy reflects the light stimulus or hue percept remains unclear. To isolate the neural correlates of subjectively experienced colors, neural responses to perceptual color representations were measured with fMRI using chromatic interocular switch rivalry (Christiansen, D'Antona & Shevell, JOV, 2017). In the experiment, two equiluminant, binocularly rivalrous chromaticities were presented to the eyes, swapping between them at a rate of 4.25 Hz. This resulted in slow perceptual alternation between two colors, with each color typically persisting for one second or longer. The chromatic stimulation in each eye was identical over a trial lasting one minute, except that the chromaticities in the two eyes were out of phase and therefore rivalrous. Also, the retinal stimulation was identical regardless of which color was perceived. We constructed an inverted encoding model for color (Brouwer & Heeger, J Neurosci, 2009) from independent training runs in which subjects viewed eight different colors without rivalry. Then, population-level color-selective responses corresponding to each perceived hue during rivalry were reconstructed in the lateral geniculate nucleus (LGN), primary visual cortex (V1), and extrastriate areas (V2, V3, V3A, V4v, and VO1). The reconstructed color responses became progressively more selective for the perceived hue across the visual system. Specifically, subjects' moment-to-moment color experiences corresponded to reconstructed color representations in V3A, V4v, and VO1. This suggests that neural representations of subjective color experience evolve across the human visual hierarchy and may emerge at later stages of cortical visual processing.

Acknowledgement: This work was supported by IBS-R015-D1.

51.25, 9:15 am **#TheShoe is the new #TheDress - a colour ambiguity involving the red-green axis needs a new explanation** Annette Werner[1](annette.werner@uni-tuebingen.de), Sabrina Fuchs[1], Ylva Kersten[1], Martha Salinas[1]; [1]Institute for Ophthalmic Research, Tuebingen University

A new phenomenon of colour ambiguity became recently known as #TheShoe, i.e., the photo of a shoe of ambiguous colours, seen in front of a dark background. The shoe is perceived as either grey leather with turquoise laces or pink leather with white laces. Spectrometric measurements revealed that the colour loci of the photo are distributed along the L/M axis. Presenting the photo of #TheShoe to 92 subjects, we found that 53 % of the observers perceived leather and laces as grey and turquoise, 34 % as pink and white and 11 % as pink and turquoise, respectively; this was independent of age and gender, and did not correlate with the perceived colours of #TheDress. Answering a questionaire, all subjects reported the scene being illuminated from the front, the colour of the light being neutral (pink/white viewers) or blue-greenish (grey/turquoise viewers). We investigated the phenomenon in more detail by having a subset of the subjects (n=20) match the colours of the shoe (presented on an 7.9" iPad display) with a colour picker program running on a separate display. The results showed a distribution of the settings along the L/M cardinal axis, whereby the settings of grey/turquoise and pink/white viewers formed distinct clusters, correlating with the individual colour names. Thus, the data show that colour ambiguities are not as rare as previously thought; importantly, such ambiguities do not seem to be specific for the daylight locus or S/(L+M) axis, as it has been suggested for the dress phenomenon. An explanation considering specific characteristics of daylight compensation is therefore not applicable in the case of #TheShoe; instead we suggest that the #TheShoe ambiguity can be explained by conflicting cues for anchoring the shoes chromaticities. Analysing the data from #TheDress we will show that similar processes can also explain the dress ambiguity.

51.26, 9:30 am **Finding the right light in the face of colour inconstancy: paintings and preferences** Anya C Hurlbert[1](anya.hurlbert@ncl.ac.uk), Naomi Gross[1], Gaurav Gupta[1]; [1]Institute of Neuroscience, Newcastle University, UK

Colour constancy is the perceptual stability of object colours under changes in the incident illumination spectrum, but it is known to be imperfect. For paintings displayed in museums, the inconstancy of colour appearance under changing illumination influences both appreciation and interpretation. Previous studies of viewers' preferences under restricted viewing conditions have demonstrated that the correlated colour temperatures (CCTs) of preferred illuminations differ from the typical museum standards (e.g. Nascimento and Masuda 2014). Here we examined how the preferred illumination chromaticity depends on the individual viewer, the painting's image statistics and pictorial content, and the overall lux level. Participants (n=16) viewed single paintings in immersive lighting provided by multi-channel LED light sources whose output spectra they controlled in real-time using joystick buttons, freely traversing all chromaticities achievable within a given lux level and which satisfied a spectral smoothness constraint. Selected illumination chromaticities were averaged over four runs, each starting at a distinct randomly selected chromaticity, for each of 5 lux levels, in separate blocks for each of 3 figurative 19th and 20th century paintings. Each block was preceded by a two-minute dark adaptation period. Results: The chromaticity of the preferred illumination depends on the lux level, individual participant and painting. Despite individual variation in settings, the preferred illumination chromaticity correlates with the mean painting chromaticity (under white light), suggesting that participants might be matching the illumination implicit in the painting.

Acknowledgement: EU (FP7-ICT-2013-11 no. 619912, HI-LED)

Tuesday AM

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Attention: Spatial modulation

Tuesday, May 22, 10:45 am - 12:30 pm, Talk Room 1

Moderator: Martina Poletti

52.11, 10:45 am **Measuring presaccadic attention without distorting it: A novel dynamic noise paradigm to investigate visuospatial attention** Nina M Hanning[1,2](hanning.nina@gmail.com), 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

Discrimination performance has become an important proxy for the analysis of visuospatial attention. In a typical paradigm, test stimuli such as characters or oriented Gabors are briefly presented at various locations in the visual field. One potential problem arising here is that these stimuli themselves constitute visual objects that may structure the visual field and thus affect what they are intended to measure, the spatial distribution of attention. We developed a novel full-field stimulus composed of orientation-filtered dynamic pink noise that allows to determine the spatio-temporal distribution of attention across the visual field, without the presence of object-like visual structures. As a remarkable property of this stimulus, we demonstrate that local discrimination performance is largely independent of visual eccentricity. This allows to directly compare attentional performance at foveal and peripheral locations. We used this stimulus to analyze the distribution of spatial attention before saccadic eye movements, and to study the effect of the presence or absence of a saccade target. Participants directed saccades according to a central cue either towards a target object or into an unstructured visual field, while simultaneously discriminating the tilt angle of an orientation filtered noise patch embedded in full screen unfiltered noise. The discrimination signal occurred briefly on a continuous range between fixation and saccade target before eye movement onset. Results show that saccades are preceded by shifts of attention even if they are directed into an unstructured visual field. The presaccadic attention shift, however, is much more focused when the saccade is directed to a target object, confirming the hypothesis that the presence of objects molds the distribution of visual attention. Results also demonstrate that the deployment of attention towards the saccade landing position is accompanied by a removal of processing resources from fixation prior to eye movement onset.

Acknowledgement: This work was supported by grants of the Deutsche Forschungsgemeinschaft (DFG) to HD (GI964/1-1 and DE336/5-1).

52.12, 11:00 am **Attention and eye movements at the foveal scale** Martina Poletti[1](martinap@bu.edu); [1]Department of Neuroscience, University of Rochester Medical Center

In humans, high visual acuity is restricted to a small (~1o) region of the retina: the foveola. Even if the foveola covers less than 1% of the visual field, the stimulus within this region can be complex, particularly when examining natural scenes. What are the roles of attention and eye movements in foveal vision? Studying attention at this scale is challenging because small eye movements continuously shift the image on the retina, covering an area as large as the foveola itself. Furthermore, localizing the line of sight within a 1 degree region is challenging and beyond the capabilities of most eye-trackers. Thanks to a combination of techniques allowing for high-resolution recordings of eye position, retinal stabilization, and accurate gaze localization, we circumvented these challenges and examined how attention and visual exploration are controlled at the scale of the foveola. Here we show that fine spatial vision in the foveola is enhanced by means of three different mechanisms: (a) Visual exploration. The precise repositioning of the preferred retinal locus by means of microsaccades enables visual exploration of foveal stimuli. Visual exploration at the foveal scale is driven by both bottom-up and top-down factors and it follows scanning strategies similar to those implemented by saccades at larger scales. (b) Covert shifts of attention. High-resolution attentional reallocations independent of eye movements improve vision at selected foveal locations. (c) Microsaccade preparation. Planning of microsaccades enhances fine spatial vision at the microsaccade future landing position at the expenses of other nearby locations within the foveola. Our findings indicate that the coupling between visual functions, oculomotor activity and attention play a crucial role in foveal vision, enabling processing of fine spatial detail during fixation.

Acknowledgement: NSF- BCS-1534932, NSF-BCS-1457238, NSF-ORA-PLUS-1420212, NIH EY18363

52.13, 11:15 am **Adaptation of Visuospatial Attention** Andrew I Wilson[1](andreww2401@gmail.com), Michael S A Graziano[1]; [1]Princeton University

When participants see an exogenous cue in a region in space, they respond more quickly to discrimination targets that subsequently appear in that region. This effect on reaction time is standardly attributed to spatial visual attention being drawn to the initial cue. We set out to determine whether this type of attention could be adapted to a spatial offset. Participants performed a simple cued discrimination task with the caveat that cues and targets were never spatially congruent. Rather, targets appeared in adjacent locations to cues. Furthermore, targets were more likely to appear (e.g. 85%) to one side of the cue than the other side. Over 384 trials of training, participants demonstrated a robust facilitation when targets appeared in the more probable location. Interestingly, the majority of participants reported no explicit knowledge of the cue-target contingencies. Following training, participants completed a generalization phase, wherein non-predictive cues appeared in novel locations. In the first 100 trail block, participants responded more quickly to targets appearing to the side of the cue that had been more probable in the training phase of the task. This effect was transient, fading in subsequent blocks. Thus, training transiently generalized to novel cue locations. Finally, in a separate experiment, participants underwent a modified training procedure wherein the cue was visually masked. Participants did not report awareness of the cue, but there was a clear attention effect for targets appearing at cued locations as opposed to adjacent locations. However, participants did not adapt to cue-target contingencies under these conditions, showing no preference for more probable adjacent locations. In summary, attention to an exogenous cue can be adapted to a spatial offset, the adaptation occurs without explicit knowledge, it generalizes to untrained spatial locations, and it is dependent on visual awareness of the cue.

Acknowledgement: Princeton Innovation Fund

52.14, 11:30 am **The Neglected Contribution of Memory Encoding in Spatial Cueing effects: A New Theory of Costs and Benefits** Brad Wyble[1](bwyble@gmail.com), Hui Chen[1]; [1]Department of Psychology, Pennylvania State University, [2]Department of Psychology, Zhejiang University

Spatial cueing effects have provided key evidence for understanding visual attention, since performance is enhanced at the cued location while being decreased everywhere else in the field. However, findings that subjects remember the location of an uninformative visual cue despite having no expectation to report it (Chen & Wyble 2015, Vision Research) suggest that subjects automatically build mental representations of the cue, and this automatic encoding may affect subsequent target report in a similar manner as the attentional blink. Our memory encoding cost (MEC) theory explains spatial cueing effects as a combination of attention and memory encoding. Unlike traditional cueing theories, which propose that invalidity costs and validity benefits are both caused by attentional allocation to the cued location, the MEC theory suggests that cueing benefits and costs stem from different sources. The theory predicts that cueing costs and benefits can be dissociated by altering the amount of information that subjects encode about the cue. Across several experiments we show that inducing subjects to encode information about a cue affects target report dramatically. Moreover we find that in typical cueing experiments without cue-report requirements, the invalidity costs are high during the start of an experiment and gradually dwindle over 200 trials, an effect which would be obscured by the standard practice of averaging across all trials. Despite the drop in costs, validity benefits remain stable, suggesting that subjects are not simply ignoring the cue, but rather learn how to use it to trigger attention without also encoding it into memory. This hypothesis was confirmed by a surprise-trial experiment, showing that subjects lost the ability to report the most recent cue's location toward the end of an experiment. This account substantially alters our understanding of visual cueing effects and suggests that visible stimuli can trigger attention without also being stored in memory.

Acknowledgement: National Science Foundation

52.15, 11:45 am **Prismatic adaptation modulates inter-hemispheric balance with a subsequent change in visual field coverage** Selene Schintu[1,3](selene.schintu2@nih.gov), Edward H. Silson[2], Zaynah M. Alam[1], Eric M. Wassermann[1], Sarah Shomstein[3]; [1]Behavioral Neurology Unit, National Institute for Neurological Disorders and Stroke, Bethesda, USA, [2]Laboratory of Brain and Cognition, Section on Learning and Plasticity, National Institute of Mental Health, Bethesda, USA, [3]Department of Psychology, George Washington University, Washington, USA

Prismatic adaptation (PA) is a simple sensorimotor technique that modulates visuospatial cognition. Right-deviating PA (rPA) ameliorates neglect symptoms in patients; whereas, left PA (lPA) produces neglect-like behavior in healthy individuals and is considered a behavioral model of neglect. PA is hypothesized to affect interhemispheric balance by inhibiting the posterior parietal cortex (PPC) contralateral to the prismatic deviation. Specifically, lPA is hypothesized to induce neglect-like behavior by inhibiting the right PPC and releasing the contralateral PPC from interhemispheric inhibition. It has been recently shown that changes in spatial attention can be measured in PPC by quantifying corresponding changes in population receptive fields (pRFs) with fMRI. Since the PPC drives PA-induced visuospatial modulation, this effect should be measurable in PPC by quantifying changes in pRFs. We hypothesized that lPA, as a model of neglect, would lead to a corresponding increase in visual field coverage for the right visual field. This would mimic the rightward hyper-attention characteristic of neglect patients. Healthy volunteers underwent fMRI before and after either lPA (n=20) or rPA (n=20). During each pRF measurement, participants were asked to fixate on a central dot, while scene fragments were displayed on the screen through a bar aperture that gradually traversed the entire visual field. Participants were asked to detect either a: (i) central dot color change (fixation condition), or (ii) presence of a particular scene (attention condition). Consistent with our prediction, lPA increased pRFs visual field coverage in the right and decreased it on the left, whereas rPA produced a different pattern. Our results provide evidence that PA affects visuospatial attention by instant reorganization of response profiles in PPC. These results have implications for understanding the contribution of interhemispheric interactions to attentional selection, as well as the utility of PA as a tool for rehabilitation, and, possibly, visual training in healthy individuals.

Acknowledgement: NSF BCS-1534823 to S. Shomstein and NINDS Intramural research support to E. M. Wassermann

52.16, 12:00 pm **Emergence of visuospatial attention in a brain-inspired deep neural network** Gregory J. Zelinsky[1,2](Gregory.Zelinsky@stonybrook.edu), Hossein Adeli[1]; [1]Department of Psychology, Stony Brook University, [2]Department of Computer Science, Stony Brook University

We show that a brain-inspired deep neural network (DNN) learns to shift its attention in order to accurately and efficiently detect objects in a search task. This model of the ATTention Network (ATTNet) consists of three interacting components: (1) early parallel visual processing (V1-V4) modeled by the convolutional layers of a CNN trained for object classification, (2) ventral processing consisting of max-pooling spatially-localized V4 feature maps to IT units, and (3) dorsal processing modelled by a Recurrent Neural Network that learns to bias features in the visual input reflecting target-category goals. ATTNet was trained using reinforcement learning on 4000 images (Microsoft COCO) of clocks, microwave ovens, or computer mice. As ATTNet greedily tried to maximize its reward it learned an efficient strategy for sampling information from an image, to restrict its visual inputs to regions offering the most evidence for being the target. This selective routing behavior was quantified as a "priority map" and used to predict the gaze fixations made by 30 subjects searching 240 images (also from COCO, but disjoint from the training set) for a target from one of the three trained categories. Target-absent trials (50%) consisted of COCO images having the same scene type ("kitchen") but not depicting the target category ("microwave"). As predicted, both subjects and ATTNet showed evidence for attention being preferentially directed to target goals, behaviorally measured as oculomotor guidance to the targets. Several other well-established findings in the search literature were observed, such as more attention shifts in target-absent trials compared to target-present. By learning to shift its attention to target-like image patterns, ATTNet becomes the first behaviorally-validated DNN model of goal-directed attention. More fundamentally, ATTNet learned to spatially route its visual inputs so as to maximize target detection success and reward, and in so doing learned to shift its "attention".

52.17, 12:15 pm **Unimpaired habit-guided spatial attention in patients with Parkinson's disease** Caitlin Sisk[1](siskx024@umn.edu), Emily Twedell[1,2], Wilma Koutstaal[1], Scott E Cooper[2], Yuhong V Jiang[1]; [1]Department of Psychology, University of Minnesota, [2]Department of Neurology, University of Minnesota

Extensive research has examined how current goals influence spatial attention. Yet the allocation of spatial attention is also guided by a search habit, which is acquired when a visual search target is frequently found in one region of space. Here, we examined the role of the dopaminergic system in acquiring and maintaining habit-guided spatial attention. Patients with Parkinson's disease (PD) and age-matched healthy controls completed a difficult visual search task. Parkinson's patients were tested in an off-medication and off-stimulator status. Unbeknownst to the participants, the target appeared most often in one quadrant in an early, training phase of the experiment. In a later, testing phase of the experiment, the target was randomly located (equally probable across all four quadrants). Healthy controls acquired an attentional preference toward the high-probability quadrant. They were faster in finding the target in the high-probability quadrant than in the other quadrants, and learning did not depend on having explicit awareness of the target's location probability. In addition, control participants maintained this attentional preference in the testing phase. Despite slower response times, Parkinson's patients also showed intact acquisition and maintenance of location probability learning. These findings contrast with PD patients' deficits in acquiring habit learning in other tasks, as found previously in probabilistic learning (the "weather prediction task"), object association learning, and spatial context learning. Our findings suggest that not all habit learning depends on the basal ganglia and the dopaminergic system, which are known to be impaired in PD. Preservation of habit-guided spatial attention may compensate for other types of attentional deficits in PD.

Acknowledgement: Engdahl Family Research Fund

Object Recognition: Neural networks

Tuesday, May 22, 10:45 am - 12:30 pm, Talk Room 2

Moderator: Philip Kellman

52.21, 10:45 am **Comparing perception in deep neural networks and humans** Georgin Jacob[1,2](georginjacob@gmail.com), RT Pramod[1,2], Harish Katti[1], SP Arun[1,2]; [1]Centre for neuroscience, Indian institute of science, Bangalore, [2]Electrical communication engineering, Indian institute of science, Bangalore

Deep neural networks have recently revolutionized computer vision with their impressive performance on vision tasks. Their object representations have been found to match neural representations in the ventral pathway. But do deep neural networks see the way we do? This is an important question because it will elucidate the conditions and computations under which perceptual phenomena might arise in neural networks optimized for object classification. Here, we selected four perceptual phenomena in humans that we tested in a state-of-the-art deep neural network (VGG-16): these were Weber's law, Thatcher effect, Mirror confusion and Global advantage. By Weber's law, humans are more sensitive to relative than absolute changes in magnitude. Across VGG-16 layers, we measured pairwise distances between unit activations in response to lines differing in length or intensity. Early layers were sensitive to absolute differences, but the later fully connected layers became sensitive to relative differences in length and intensity. In the Thatcher effect, humans are more sensitive to part inversion in upright but not inverted faces. Again, later layers of a face neural network (VGG-face) exhibited greater sensitivity to upright face changes. In mirror confusion, humans find lateral mirror images more similar than horizontal mirror images. Here too, mirror confusion

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increased across layers of the neural network. Finally, we tested the global advantage effect, in which humans are more sensitive to changes in global shape compared to local shape. Here, deep neural networks showed the opposite trend: later layers were more sensitive to local changes in hierarchical stimuli. Thus, deep networks exhibit some but not all perceptual phenomena. We propose that closely comparing deep networks with human perception can bring interesting insights.

Acknowledgement: Wellcome-DBT India Alliance, DBT-IISc partnership program

52.22, 11:00 am **Population receptive fields in high-level visual cortex are tuned for specific categories** Edward H Silson[1](ed.silson@nih.gov), Richard C Reynolds[2], Daniel Janini[1], Chris I Baker[1], Dwight J Kravitz[3]; [1]Section on Learning & Plasticity, Laboratory of Brain & Cognition, National Institute of Mental Health, Bethesda, MD, USA., [2]Scientific and Statistical Computing Core, National Institute of Mental Health, Bethesda, MD, USA., [3]3. Department of Psychology, The George Washington University, 2125 G St, NW, Washington DC 20052, USA

High-level visual cortex contains regions that selectively and differentially process certain categories, such as words, scenes and faces, but little is known about how they are optimized to support such processing. Here, using a population receptive field (pRF) model that allows for estimates of elliptical and orientated pRFs, we show that two regions, the visual word form area (VWFA) and parrahippocampal place area (PPA), which subserve word reading and scene processing, respectively, integrate information across visual space in vastly different ways, each optimized to support their preferred category. Eighteen participants completed pRF mapping experiments and category-selective functional localizers. A combination of group-based and individual participant data was used to define VWFA, whereas PPA was defined in each individual. Word-selective cortex VWFA contained pRFs that were simultaneously foveal, elliptical, and predominantly horizontal, the ideal parameters for recognizing word forms, whilst those in scene-selective PPA were peripheral, more circular, and more broadly tuned in orientation. Importantly, these pRF patterns also differ from those observed in early visual cortex, highlighting different processing mechanisms between low- and high-level visual regions. These differing patterns of pRF properties suggest that high-level visual cortex is fundamentally optimized to support the processing of specific visual categories through the differential integration of information across visual space.

Acknowledgement: Intramural Research program of the National Institutes of Health

52.23, 11:15 am **Do Deep Neural Networks Suffer from Crowding?** Gemma Roig[1,2](gemmar@mit.edu), Anna Volokitin[3], Tomaso Poggio[1]; [1]Center for Brains Minds and Machines, MIT, [2]ISTD, Singapore University of Technology and Design, [3]CVL, ETH Zurich

Crowding is a visual effect suffered by humans, in which an object that can be recognized in isolation can no longer be recognized when other objects, so called clutter, are placed close to it. In this work, we study the effect of crowding in artificial Deep Neural Networks (DNNs) for object recognition. We analyze both deep convolutional neural networks (DCNNs) as well as an extension of DCNNs that are multi-scale and that change the receptive field size of the convolution filters with their position in the image, called eccentricity-dependent models. The latter networks have been recently proposed for modeling the feedforward path of the primate visual cortex. Our results reveal that incorporating clutter into the images of the training set for learning the DNNs does not lead to robustness against clutter not seen at training. Also, when DNNs are trained on objects in isolation, we find that recognition accuracy of DNNs falls the closer the clutter is to the target object and the more clutter there is. We find that visual similarity between the target and clutter also plays a role and that pooling in early layers of the DNN leads to more crowding. Finally, we show that the eccentricity-dependent model trained on objects in isolation can recognize such target objects in clutter if the objects are near the center of the image, whereas the DCNN cannot.

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52.24, 11:30 am **Can deep learning networks acquire the robustness of human recognition when faced with objects in visual noise?** Hojin Jang[1](hojin.jang@vanderbilt.edu), Frank Tong[1]; [1]Department of Psychology and Vanderbilt Vision Research Center, Vanderbilt University

Convolutional neural networks (CNNs) have attracted considerable attention for their remarkable performance at a variety of cognitive tasks, including visual object recognition. This has led to the proposal that deep learning networks may provide a biologically plausible model of human visual processing (e.g., Yamins et al., 2014; Khaligh-Razavi & Kriegeskorte, 2014). Here, we investigated whether these networks are robust to noisy viewing conditions. If not, are CNNs disrupted by visual noise in a manner that resembles human performance? To this end, we systematically compared the performance of humans and machines across a range of signal-to-noise ratios by presenting object images in varying levels of Gaussian pixel noise or Fourier phase-scrambled noise. Human performance proved far more robust to noise than state-of-the-art CNNs (AlexNet, VGG, and GoogLeNet). Moreover, CNNs were more severely impaired by Gaussian noise while humans had greater difficulty with spatially structured Fourier noise, implying that these CNNs process noisy objects in a qualitatively different manner. Next, we asked whether CNNs can acquire greater robustness by undergoing training with noisy object images. Noise-trained CNNs showed major improvements and successfully generalized to novel noisy images, demonstrating that noise invariance can be achieved by feedforward neural architectures through supervised learning. A layer-specific network analysis revealed that the middle and upper layers underwent the greatest change by acquiring representations that were more robust to visual noise following this training regime. Finally, we evaluated the patterns of error responses made by CNNs and humans by comparing their confusion matrices. After noisy image training, CNNs made patterns of errors that more strongly resembled those made by humans for objects in high levels of noise. Taken together, these results suggest that CNNs provide a promising model for gaining insight into the robustness of human object recognition performance.

52.25, 11:45 am **Deep Convolutional Networks do not Make Classifications Based on Global Object Shape** Nicholas Baker[1](nbaker9@ucla.edu), Hongjing Lu[1], Gennady Erlikhman[2], Philip J Kellman[1]; [1]University of California, Los Angeles, [2]University of Nevada, Reno

Deep convolutional networks (DCNNs) have achieved previously unseen performance in object classification, raising questions about whether DCNNs operate similarly to human vision. In biological vision, shape is arguably the most important cue for recognition. We tested whether DCNNs utilize object shape information. In Experiments 1 and 2, we tested DCNNs on shapes lacking typical context and surface texture, using glass figurines and silhouettes. The network showed no ability to classify glass figurines but correctly classified some silhouettes. Specific aspects of the results led us to hypothesize that DCNNs do not distinguish object's bounding contours from other edge information, and that DCNNs access some local shape features, but not global shape. In Experiment 3, we scrambled correctly classified silhouette images to test classification accuracy when local features were preserved but global shape was disrupted. DCNNs gave the same classification labels despite disruptions of global form that reduced human accuracy to 28%. In Experiment 4, we retrained the decision layer of a DCNN to discriminate between circles and squares. Then, we tested the network on circles composed of local half-square elements and squares composed of half-circle elements. The network classified the former as squares and the latter as circles. In Experiment 5, we attempted to retrain the decision layer of a DCNN to discriminate between circles and ellipses. The network was unable to learn this discrimination, maintaining chance performance even after extended training. These results provide evidence that DCNNs may have access to some local shape information in the form of local edge relations, but they have no access to global object shapes.

52.26, 12:00 pm **Using multiple optimization tasks to improve deep neural network models of higher ventral cortex** Chengxu Zhuang[1](chengxuz@stanford.edu), Daniel L.K. Yamins[1,2]; [1]Department of Psychology, Stanford University, [2]Computer Science Department, Stanford Neurosciences Institute, Stanford University

Recent goal-driven deep neural network (DNN) models of higher ventral visual cortex have leveraged the rich behavioral task of object recognition to impose powerful top-down constraints on network parameters. DNNs optimized to solve the multi-way object categorization in challenging real-world images have been shown to provide state-of-the-art predictions of neural responses in visual areas throughout the primate ventral pathway. Here, we show that such models can be improved by using a combination of multiple behaviorally realistic tasks as network optimization targets. Specifically, we optimized a DNN to simultaneously solve high level tasks including object categorization and scene classification, as well as intermediate visual tasks including depth estimation, normal map estimation and semantic segmentation. Task optimization was synergistic, in that performance levels for each task in the combined training were higher at a given number of training examples than for models trained on each task separately. Moreover, the model trained on the combined tasks provided improved ability to fit response patterns in neurons from both cortical areas V4 and IT. These results suggest that identifying a richer and more ecologically relevant variety of visual behaviors as network "goals" may lead to substantially improved understanding of the neural computations in the visual system.

52.27, 12:15 pm **The essential role of recurrent processing during object recognition under occlusion** Karim Rajaei[1](karim.rajaei@gmail.com), Yalda Mohsenzadeh[2], Reza Ebrahimpour[3,1], Seyed Mahdi Khaligh Razavi[4,5]; [1]School of Cognitive Sciences (SCS), Institute for Research in Fundamental Sciences (IPM), Niavaran, P.O. Box 19395-5746, Tehran, Iran, [2]McGovern Institute for Brain Research, MIT, Cambridge, MA, US, [3]Cognitive Science Research Lab., Department of Electrical and Computer Engineering, Shahid Rajaee Teacher Training University, P.O. Box 16785-163, Tehran, Iran, [4]Computer Science and AI Lab (CSAIL), MIT, Cambridge, MA, US, [5]Department of Brain and Cognitive Sciences, Cell Science Research Center, Royan Institute for Stem Cell Biology and Technology, ACECR, Tehran, Iran

Several recent findings have indicated that the core object recognition is primarily solved through the feedforward sweep of visual information processing. On the other hand, while recurrent connections are ubiquitous in our visual system, their role in object-processing is not yet fully understood. Here, we investigated the contribution of recurrent processes in object recognition under a prevalent challenging condition, that is when objects are occluded by other natural or artificial occluders in the environment. To characterize neural dynamics of object recognition under occlusion, we acquired magnetoencephalography(MEG) data (N=15 subjects), while subjects were presented with images of objects with 0%(no-occlusion),60% and 80%occlusion –with and without backward-masking. We provide evidence from multivariate analysis of MEG data, behavioral data, and computational modelling, demonstrating an essential role for recurrent processes in object recognition under occlusion. First, multivariate analysis of MEG data showed that object discrimination is significantly delayed (by~60ms) under occlusion compared to the no occlusion condition(p< 10^-4, two-sided signrank-test), likely due to the additional time needed for recurrent processes. Second, temporal generalization analysis (King&Dehaene,2014), which provides information about temporal organization of information processing stages, showed that initial sensory signals undergo a relatively long sequence of processing stages that involve recurrent interactions to establish a discriminative representation of occluded objects. Third, backward-masking which is thought to disrupt recurrent processes, impaired MEG object-discrimination time-courses, and subjects' behavioral performances only under occlusion. Fourth, a feedforward CNN failed to explain the MEG data and the behavioral data when objects were occluded; however, a CNN with local recurrent connections reached the human-level performance under occlusion, and partially explained the MEG data for occluded objects. Taken together, our empirical results suggest an essential role for recurrent processing when objects are occluded, and our computational model with local recurrent connections explains how our brain might be solving this problem.

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Tuesday Morning Posters

Faces: Neural mechanisms 1

Tuesday, May 22, 8:30 am - 12:30 pm, Banyan Breezeway

53.301 Isolating rapid and automatic human facial expression categorization

Fanny Poncet[1](fanny.poncet@u-bourgogne.fr), Milena P Dzhelyova[2], Jean-Yves Baudouin[1], Bruno Rossion[2,3], Arnaud Leleu[1]; [1]Group "Developmental Ethology and Cognitive Psychology", Centre des Sciences du Goût et de l'Alimentation, AgroSup Dijon, CNRS, INRA, Université Bourgogne Franche-Comté, F-21000 Dijon, France, [2]Psychological Sciences Research Institute and Institute of Neuroscience, Université catholique de Louvain (UCL), 1348 Louvain-la-Neuve, Belgium, [3]Service de Neurologie, Centre Hospitalier Universitaire de Nancy, 54035 Nancy, France

Efficient understanding of emotions from expressive faces is crucial for human interactions. Specific human electrophysiological responses to brief neutral-to-emotion changes of facial expression can be isolated in a few minutes, without explicit task, with fast periodic visual stimulation (Dzhelyova et al., 2017). Here we aimed at extending these observations to the categorization of human basic facial expressions. We recorded scalp EEG from 15 participants (10 females). In experiment 1, a neutral face was presented 6 times per second (i.e., 6 Hz) and the same face expressing an emotion (i.e., anger, disgust, fear, happiness or sadness in different sequences) appeared every five pictures to measure detection of facial expressions at the 1.2 Hz frequency. Participants performed an orthogonal task (fixation circle-to-square change detection) throughout the stimulation. In experiment 2, a specific facial expression also appeared at the 1.2 Hz rate but all other facial expressions were randomly displayed in between. Hence, expression-changes intervened at 6 Hz and only the categorization of a specific emotional expression is measured at 1.2 Hz. Significant 1.2 Hz (and harmonics, 2.4 Hz, etc.) responses were found in both experiments in the EEG spectra, showing that the categorization of an emotional expression can be isolated irrespective of expression-change detection. A decoding approach reveals distinct topographies between the different emotions in both experiments. However, decoding performance was greater than chance for all emotions only in experiment 2, which isolates facial categorization from general expression-change detection processes. Overall, these findings indicate that rapid emotion categorization exempt from more general expression-change detection processes can be objectively (i.e., at pre-determined frequencies) isolated in the human brain in a few minutes of recording and support partly distinct neural sources for the visual processing of different emotion categories. Keywords: Fast Periodic Visual Stimulation, EEG, frequency-tagging, facial expression, detection, categorization.

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53.302 An objective signature of emotional expressions and context integration within a single glance: evidence from electroencephalographic frequency-tagging

Stéphanie Matt[1](-stephanie.matt@univ-lorraine.fr), Joan Liu-Shuang[2], Louis Maillard[3], Joëlle Lighezzolo-Alnot[4], Bruno Rossion[2], Stéphanie Caharel[1]; [1]Laboratoire INTERPSY – 2LPN (EA4432) - Université de Lorraine (France), [2]Institute of Research in Psychological Science, Institute of Neuroscience, University of Louvain (Belgium), [3]CRAN (UMR 7039 CNRS) - CHU de Nancy - Université de Lorraine (France), [4]Laboratoire INTERPSY (EA4432) – Université de Lorraine (France)

The ability to quickly and accurately extract someone's emotional state from their face is crucial for social interaction. Over the last decades, the processing of emotional expressions has been studied mainly using isolated faces. However, at the behavioral level, contextual information often leads to radical changes in the categorization of facial expressions, yet the underlying mechanisms are not well understood (Aviezer et al., 2017, Current Opinion in Psychology, 17, 47–54; Barrett et al., 2011, Current Directions in Psychological Science, 20, 286 –290). Here we examined the impact of emotional visual scenes on the perception of emotional expressions within a single glance by means of fast periodic visual stimulation (FPVS). We recorded 128-channel EEG while participants viewed 60s sequences with a dual frequency-tagging paradigm (Boremanse et al, 2013, Journal of Vision (11):6, 1-18). We presented faces and scenes simultaneously, with each stimulus set flickering at specific frequency (f1=4.61 Hz and f2=5.99 Hz; frequencies were counterbalanced across stimuli). Each sequence displayed different faces with the same emotional expression (disgust, fear, or joy) within either positive or negative valence visual scenes. Periodic EEG responses at the image presentation frequencies (4.61 Hz and 5.99 Hz) captured general visual processing of the emotional faces and scenes, while intermodulation components (e.g. f2-f1: 5.99 – 4.61 Hz = 1.38 Hz) captured the integration between the emotional expressions and their context. At the group-level, emotional expressions elicited right-lateralized occipito-temporal electrophysiological responses that were stronger for negative valence expressions (especially disgust). Similarly, negative scenes elicited stronger neural responses than positive scenes over the medial occipital region. Finally, and critically, we observed intermodulation components that were prominent over right occipito-temporal sites and showed increased response amplitude for negative scenes, thereby providing an objective demonstration of the perceptual integration of emotional facial expressions with their emotional context.

53.303 N170 sensitivity to the horizontal information of facial expressions

Justin Duncan[1,2](justin.duncan@mail.mcgill.ca), Frédéric Gosselin[3], Caroline Blais[1], Daniel Fiset[1]; [1]Université du Québec en Outaouais, [2]Université du Québec à Montréal, [3]Université de Montréal

The N170 event-related potential, which is preferentially tuned to faces (see for review Rossion, 2014), has been linked with processing of the eyes (Rousselet, Ince, van Rijsbergen & Schyns, 2014), of diagnostic facial features of emotions (Schyns, Petro & Smith, 2007), and of horizontal facial information (Jacques, Schiltz & Goffaux, 2014). Recent findings have shown that horizontal information is highly diagnostic of the basic facial expressions, and this link is best predicted by utilization of the eyes (Duncan et al., 2017). Given these findings, we were interested in how N170 amplitude relates with spatial orientations in a facial expressions categorization task. Five subjects each completed 7,000 trials (1,000 per expression) while EEG activity was measured at a 256 Hz sampling rate. Faces were randomly filtered with orientation bubbles (Duncan et al., 2017) and presented on screen for 150ms. Performance was maintained at 57.14%, using QUEST (Watson & Pelli, 1983) to modulate stimulus contrast. The signal was referenced to the mastoid electrodes and band-pass filtered (1-30 Hz). It was epoched between -300 and 700 ms relative to stimulus onset, and eye movements were removed using ICA. Single-trial spherical spline current source density (CSD) was computed using the CSD toolbox (Kayser & Tenke, 2006; Tenke & Kayser, 2012). Our main analysis consisted in conducting a multiple linear regression of single-trial orientation filters on PO8 voltages at each time point. The statistical threshold (Zcrit= 3.6, $p < .05$, two-tailed) was established with the Stat4CI toolbox (Chauvin et al., 2005). We found a negative correlation between horizontal information availability and voltage (Zmin= -5.43, $p < .05$) in the 50ms leading up to the N170's peak. Consistent with the proposition that the N170 component reflects the integration of diagnostic information (Schyns, Petro & Smith, 2007), the association between horizontal information and amplitude was strongest 25 ms before the peak, and completely disappeared at peak.

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53.304 **Cortical activation of fearful faces requires central resources: multitasking processing deficits revealed by event-related potentials** Amélie Roberge[1](amelie.roberge@uqtr.ca), Justin Duncan[2-3], Ulysse Fortier-Gauthier[1], Daniel Fiset[2], Benoit Brisson[1]; [1]Département de psychologie, Université du Québec à Trois-Rivières, [2]Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais, [3]Département de Psychologie, Université du Québec à Montréal

To investigate if emotional face processing requires central attention, a psychological refractory period paradigm was combined with the event-related potential (ERP) technique. Participants were asked to categorize tones as high (900 Hz or 2000 Hz) or low (200 Hz or 426 Hz) as quickly and accurately as possible and then to indicate if a face expressed fear or a neutral expression. Stimulus onset asynchrony (SOA) between the presentation of the tone and the face was manipulated (SOA: 300, 650 or 1000ms) to vary the amount of central attention available to perform the face expression task (less central attention available at short than long SOAs). The amplitude of frontally distributed ERP components associated to emotional face processing (computed as the difference between fear and neutral conditions: Eimer & Holmes, 2007) were measured at all SOAs. The first component (175-225 ms post-visual stimulus onset), which is thought to reflect rapid initial detection of the emotion, was not affected by SOA, $F(2,50) = 2.24$, $p = .12$. However, a significant effect of SOA was observed on a later sustained frontal positivity (300-400 ms post-visual stimulus onset), that is thought to reflect the conscious evaluation of emotional content, $F(2,50) = 5.33$, $p = .01$. For both components, no effect of SOA was observed in a subsequent control experiment in which both stimuli were presented but only a response to the expression of the face was required, $F(2,32) = 2.80$, $p = .10$ and $F(2,32) = 1.26$, $p = .30$. These results suggest that the rapid perceptual detection of the facial expression is independent of central attention. In contrast, the subsequent cognitive stage of conscious evaluation of emotional content does require central attention to proceed.

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53.305 **Nasal Oxytocin produces emotion dependent effects on early visual evoked potentials.** David P Crewther[1](dcrewther@swin.edu.au), Laila Hugrass[1], Ariane Price[1], Izelle Labuschagne[2]; [1]Centre for Human Psychopharmacology, Swinburne University of Technology, [2]Cognition and Emotion Research Centre, Australian Catholic University

The rapid evaluation of low-level perceptual features of a face has high ecological value, allowing rapid detection of emotion and threat. The level of vigilance is enhanced in those with social anxiety and high autistic tendencies. The existence of a direct, low spatial frequency, subcortical route to the amygdala, via the pulvinar, has been postulated. Oxytocin (OXT) has shown potential benefit for Social Anxiety Disorder as well as for autism, through regularisation of amygdala activity. OXT research has largely focused on neuroimaging of the social brain, with relatively few studies of the interaction of OXT and visual sensory processing. Using a cross-over double-blind placebo-controlled design with 27 neurotypical young adult males, we tested the psychophysical and electrophysiological effects of nasally administered OXT and placebo. EEG recordings over occipital and parietal cortex were taken during the visual recognition tasks. In addition, multifocal visual evoked potentials were recorded so that any variation in afferent magnocellular and parvocellular activity could be measured. Using paired t-tests, significant differences were observed in several of the facial emotion evoked responses comparing OXT and placebo administration. For the P100 peak with fearful faces, mean amplitude was reduced under OXT cf Placebo for left hemisphere electrodes (P7, PO7), and increased for Happy face stimuli. No differences were recorded for Neutral faces, nor for N170 peaks. Also right hemisphere (P8, PO8) recordings were not different. The multifocal VEP showed an OXT cf Placebo latency advance in the grand mean average waves for the early (N70) peaks of the first order kernel and the first slice of the second order kernel (K2.1), responses that have been previously been linked to magnocellular function. It appears that intranasal OXT is projecting effects of emotional visual processing onto visual parietal and occipital cortex. This situation could reflect modulation of an amygdala-pulvinar-MT/V5 interaction.

53.306 **Sustained attention for categorical decision of uncanny faces as marked by delayed latency of P3 component** Daegyu Kim[1](se2p@cau.ac.kr), Hyeri Moon[1], Minkyu Hwang[1], Phil-sik Jang[2], Woo Hyun Jung[3], Joo-seok Hyun[1]; [1]Department of Psychology, Chung-Ang University, [2]Department of IT & Logistics, Sehan University, [3]Department of Psychology, Chungbuk National University

Uncanny experience refers to the phenomenon that human-like objects, such as android robots or animated cartoons, elicit eerie feeling of unfamiliarity even if they considerably resemble humans (Mori, 1970). To understand the cognitive mechanism of this phenomenon, we used an oddball task for three face categories, for which their event-related potentials(ERPs) were simultaneously recorded. Uncanny faces were constructed by synthesizing facial contours and volumes sampled from a set of cartoon faces with skin textures obtained from another set of human faces. In the oddball task, participants reported human faces as an infrequent target (20% probability of trial occurrence), cartoon faces as a frequent standard (60%), and uncanny faces as an infrequent deviant (20%). After the ERPs recording session, the participants rated familiarity and human-likeness on a Likert scale. While the P3 amplitude measured from the target trials (i.e., human) was greater, the P3 latencies were notably shorter than the deviant trials (i.e., uncanny). Participants also rated lowest familiarly with the uncanny faces, nevertheless rating identical human-likeness between the uncanny and cartoon faces. These results suggest that the uncanny faces as a non-target deviant initially attracted less attention than the human face target; however, the subsequent perception of their uncanniness may have further sustained the participant's attention than the target until their categorical decision was complete.

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53.307 **Decoding facial expressions across non-overlapping face features in early visual cortex** Fraser W Smith[1](Fraser.Smith@uea.ac.uk), Lucy S Petro[2], Lars Muckli[2], Vicky S Adams[1]; [1]School of Psychology, University of East Anglia, [2]Institute of Neuroscience & Psychology, University of Glasgow

Neurons in the early sensory areas are subject to multiple sources of influence, spanning information coming from the sensory input, local processing and higher brain regions. Visual occlusion is a particularly challenging problem that is thought to require the involvement of such top down and recurrent connections. In the present study we investigated the role of early visual and higher level brain regions in processing occluded facial expressions, using a novel paradigm that allows the dissociation of bottom-up from recurrent influences (see Greening et al, Cortex, in press). We presented observers with occluded face stimuli revealing different portions of the face in different conditions (eye region, mouth region, or face with eyes hidden, or face with mouth hidden) and investigated the similarity of the brain responses to non-overlapping visual inputs (e.g. eyes to face minus eyes). Participants fixated and performed either an expression or gender categorization task on the same stimulus set. Retinotopy was used to define V1-V3 and Neurosynth to define higher level regions of interest. MVPA decoding analyses revealed that strikingly in primary visual cortex, similar responses could be observed to non-overlapping face regions (e.g. eye region to face minus eye region) while in EVC similar responses were present across the most non-overlapping inputs (eye region to mouth region) but only during emotion recognition. Evidence was also present in high level regions (e.g. STS) of generalization across non-overlapping face inputs (replicating Greening et al., in press) suggesting cortical feedback may generate the spatial generalization effects found in early visual cortex. Importantly, low level control analyses provided no evidence whatsoever of reliable decoding across non-overlapping face inputs. In sum our results suggest that recurrent connections (top down or local) faciliate the reactivation of occluded parts of face stimuli, even in the early visual areas.

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53.308 **Emotion-specific categorization-relevant information reconstructed from Right and Left Fusiform Gyri** Nicola van Rijsbergen[1](nicola@psy.gla.ac.uk), Robin A.A. Ince[1], Philippe G. Schyns[1]; [1]Institute for Neuroscience and Psychology, University of Glasgow

An observer's behavior in categorization tasks depends both on information encoded from their visual field, and task constraints. Where, when and how does the brain's dynamic encoding of visual information interact with task demands to generate a task-relevant representation? Eight observers categorized emotions in a 7AFC task, on "Bubbled" face stimuli while we recorded MEG responses. Using mutual information, we measured the spatio-temporal course of categorical response information in each observer, locating spatio-temporal regions where MEG activity is predictive of observer response. Response information ($p< 0.05$, corrected), also representing sensitivity to stimulus category, develops in occipital cortex during the early M170, and shows additional spatio-temporal loci common across observers in the rFG (n=7) and lFG (n=8). We then measured the spatio-temporal course of stimulus feature information. During the encoding window of the M170 (up to 250ms), only on average 55% [range 49-95%] of features encoded in occipital cortex reach the lFG and rFG), suggesting selective transmission, with differing feature information on left and right. The proportion of feature information encoded in FG was greater for 'happy', with no other differences between other expressions. To examine how observer response interacts with stimulus feature coding within category, we quantified the representational overlap between response information (computed as correct category decision versus incorrect), and stimulus feature coding, using behavioral redundancy. Redundancy quantifies how much of the trial-by-trial stimulus variation commonly affects both MEG signal and the observer's behavioral response. The proportion of significantly behaviorally relevant features with redundancy in the FG varied with expression, with Happy, Disgust, and Angry showing more redundancy consistently across observers. These results suggest redundancy is tapping an expression dependent process in the Fusiform Gyrus over and above an initial feature selection.

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53.309 **Neural mechanisms of perceptual confusion of facial emotions** Yingying Wang[1](yywang0415@163.com), Fang Fang[1,2,3,4,5]; [1]Peking-Tsinghua Center for Life Sciences, Peking University, [2]School of Psychological and Cognitive Sciences, Peking University, [3]Beijing Key Laboratory of Behavior and Mental Health, Peking University, [4]IDG/ McGovern Institute for Brain Research, Peking University, [5]Key Laboratory of Machine Perception (Ministry of Education), Peking University

It has been long debated on whether the emotion system is subserved by six discrete basic emotion categories (i.e., disgust, anger, fear, happiness, sadness, and surprise). Recent studies showed that perceptual confusion often occurred between fear and surprise and between disgust and anger. arguing for the existence of less than the six basic emotions. However, the neural mechanisms of the confusions are still unknown. To answer this question, we presented subjects with face pictures expressing the six basic emotions and the neutral emotion, while measuring their BOLD signals. We performed multivariate pattern analysis (MVPA) to classify or decode BOLD response patterns between the six basic emotions and the neutral emotion. We found that, in the amygdala, both fear and surprise can be decoded significantly above chance level, and in the superior temporal sulcus (STS), disgust and anger can be decoded significantly above chance level. To further understand the confusion effects, we performed cross-category MVPA, in which a decoder was trained with one emotion (vs. neutral face) and was then applied to decode other emotions (vs. neutral face). The cross-category decoding accuracy was significant between disgust and anger in the STS. However, the decoding accuracy between surprise and fear was not significant in the amygdala. Notably, neither the within- nor cross-category decoding accuracy was significant in face-selective visual areas, including occipital face area (OFA) and fusiform face area (FFA). These findings imply that perceptual confusion between certain emotions (e.g., disgust and anger) is likely to occur at the emotion processing level, rather at the pure visual processing level.

53.310 **Decoding dynamic facial expressions in both macaque and human** Hui Zhang[1](hui.zhang@buaa.edu.cn), Shruti Japee[2], Leslie G. Ungerleider[2]; [1]Beijing Advanced Innovation Center for Big Data and Brain Computing (BDBC), Beihang University, 100083 Beijing, China, [2]Laboratory of Brain and Cognition, National Institute of Mental Health, Bethesda, MD 20892, United States

Abundant evidence has shown that dynamic facial expressions are better discriminated than static expressions. However, the underlying neural mechanism for this enhanced ability remains unclear. The aim of the current study was to gain insight into the underlying neural substrate for this phenomenon in both monkeys and humans. Four male macaque monkeys were injected with MION prior to being scanned at 4.7T in a slow event-related fMRI experiment. During scanning, they viewed video clips of 16 monkey faces belonging to four identities and having four expressions: fear grin (fearful), threat (aggressive), lip smack (submissive) and neutral. The 23 human subjects participated in a slow event-related fMRI experiment at 7T, in which they viewed videos of 32 human faces belonging to eight identities and having four expressions: fearful, angry, happy and neutral. Motion energy in each video clip was evaluated using an optic flow algorithm, and was regressed out in the general linear model analyses of the fMRI data. A Support Vector Machine (SVM) was then used on the patterns of the fMRI response to determine how well each class of facial expression was decoded from all other facial expressions. The results indicated that, in monkeys, both the anterior fundus (AF) and middle fundus (MF) face patches showed significant decoding performance for discriminating emotional facial expressions from neutral expressions; the decoding performance in MF was significantly higher than in AF. In humans, face-selective regions in anterior STS, middle STS and posterior STS showed significant decoding performance for discriminating emotional expressions from neutral expressions; the decoding performance in posterior STS was significantly higher than in anterior STS. Taken together, our results suggest that monkeys and humans share similar neural computations for discriminating dynamic facial expressions along the STS that is most evident posteriorly. Supported by the NIMH IRP.

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Faces: Disorders

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53.311 **An updated cortical face network analysis of the prosopagnosic patient PS with fast periodic stimulation** Xiaoqing Gao[1](dr.x.gao@gmail.com), Quoc Vuong[2], Bruno Rossion[1,3]; [1]Psychological Sciences Research Institute, Institute of Neuroscience, University of Louvain, Belgium, [2]Institute of Neuroscience, Newcastle University, [3]Neurology Unit, Centre Hospitalier Regional Universitaire (CHRU) de Nancy, F-54000 Nancy, France

Following brain damage, the patient PS suffers from a selective impairment in recognizing individuals by their faces, i.e. prosopagnosia. Her case has been documented in more than 30 publications, informing about the nature of individual face recogition and its neural basis. Here we report original fMRI data obtained on this patient with a recently developed fast periodic stimulation (FPS) approach combining high sensitivity, specificity and reliability in identifying the cortical face-selective network (Gao et al., 2017; Experiment 1). In Experiment 2, we test for sensitivity to differences between individual faces with FPS-fMRI. We show that the large face-selective activation in the lateral section of the right middle fusiform gyrus, i.e. right FFA, forms a single cluster of activation from the anterior border of the patient's main lesion in the inferior occipital gyrus. The contribution of posterior face-selective responses in the right or left inferior occipital gyrus is ruled out, further supporting the previous evidence that face-selective response emerges in the right middle fusiform gyrus of the patient's brain from non-face-selective inputs from early visual areas. Despite this, we find no evidence that low-level visual cues, i.e. amplitude spectrum of images, contribute to neural face-selective responses anywhere in the patient's cortical face network. This sensi-

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tive face localizer approach also reveals an intact face-selective network anterior to the fusiform gyrus, inclusing clusters in the ventral anterior temporal lobe (occipito-temporal sulcus and temporal pole) and the inferior frontal gyrus, with a right hemispheric dominance. Overall, with the exception of the left inferior occipital gyrus (IOG), the cortical face network of the prosopagnosic patient PS appears remarkably similar to typical individuals in non-brain damaged regions. However, as shown in Experiemnt 2, unlike in the normal brain, the patient's face network is insensitive to differences between individual faces, in line with her prosopagnosia.

53.312 **Developmental prosopagnosics have widespread selectivity reductions in category-selective areas** Jiahui Guo[1](Jiahui.Guo.GR@dartmouth.edu), Hua Yang[2], Brad Duchaine[1]; [1]Dept. of Psychological and Brain Sciences, Dartmouth College, [2]University of Massachusetts Medical School, USA

It remains unclear which face-selective areas contribute to DP, whether areas outside the face processing system play a role in DPs' deficits with faces, and whether DPs show reduced selectivity in other category-selective areas. To address these issues, we scanned 22 DP participants and 27 controls with a dynamic localizer as well as areas selective for scenes, bodies, and objects. To avoid the complications inherent in comparing groups using typical threshold-based approaches, we analyzed each category-selective area by selecting a fixed percentage of the most selective voxels for each anatomical region that typically contains a category-selective response and then systematically probed the effect of ROI size on category-selectivity. DP face selectivity was reduced in all 12 face ROIs and was significantly reduced in four right hemisphere ROIs and left FFA. In all cases, the face-selectivity reductions were driven by weaker responses to faces. Selectivity differences in ventral and dorsal ROIs as well as anterior and posterior ROIs were comparable. Results for other category-selective ROIs were mixed. DPs showed reduced selectivity in all three scene-selective areas in the right hemisphere (PPA, OPA, RSC), and a signficiant reduction in left PPA. In body-selective ROIs, DPs showed marginally reduced selectivity in EBA bilaterally and non-significant reductions in FBA bilaterally. Object-selectivity in bilateral lateral occipital cortex (LO) and bilateral posterior fusiform (pFs) was normal. Selectivity reductions for faces and other categories were restricted to ROI that showed a preferential response to that category. In summary, DPs have widespread selectivity reductions throughout the face processing system. Reduced selectivity was also present in a number of areas selective for non-face categories. These findings suggest many DPs have broad impairments involved in visual recognition.

53.313 **Varieties of holistic processing deficits in developmental prosopagnosia** Angus Chapman[1,2], Lauren Bell[1], Brad Duchaine[3], Tirta Susilo[1]; [1]School of Psychology, Victoria University of Wellington, [2]Department of Psychology, University of California, San Diego, [3]Department of Psychological and Brain Sciences, Dartmouth College

Face recognition is thought to rely on "holistic processing" – a style of perceptual mechanisms that bind facial features together for face identification. Many researchers propose that disruption of holistic processing is causally implicated in developmental prosopagnosia, but whether holistic processing in developmental prosopagnosia is reduced or completely abolished remains unclear. Here we report a large and comprehensive online study of holistic processing in developmental prosopagnosia. We tested 124 prosopagnosics and 124 sex/age-matched controls with three classic tasks of holistic processing: the inversion task, where identification of a face is much more difficult when the face is shown upside-down; the composite task, where matching two top-halves of faces is more difficult when they are paired with different bottom-halves; and the part-whole task, where discrimination of a target feature (eyes, nose, or mouth) is more difficult when the feature is shown alone than in a whole face. Prosopagnosics showed significant holistic effects across all tasks (inversion: 16.6%; composite: 15.2%; part-whole: 2.5%), but they were reduced compared to the effects in controls (inversion: 26.0%; composite: 20.2%; part-whole: 8.6%). Interestingly, the size of the reduction varied depending on task (inversion: 36.1% reduction relative to controls; composite: 24.8%; part-whole: 71.4%), suggesting that disruption of holistic processing in developmental prosopagnosia is not a unitary phenomenon. The reduced holistic effects in prosopagnosics appear to originate in typical mechanisms, because prosopagnosics showed little or no holistic effects with inverted faces in the composite and part-whole tasks. Our study provides robust evidence that developmental prosopagnosia is associated with reduced, not abolished, holistic processes, and sheds light on the nature and role of holistic processing in normal face recognition. Our study also demonstrates the value of online studies testing large numbers of participants in neuropsychology research.

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53.314 **Facial identity and facial expression processing dissociate in developmental prosopagnosia** Lauren C Bell[1](laurenbell@windowslive.com), Tirta Susilo[1]; [1]Victoria University of Wellington

Individuals with developmental prosopagnosia present lifelong deficits recognising facial identity, but their ability to process facial expression is unclear. Addressing this issue is key for understanding the core deficit in developmental prosopagnosia, and for advancing knowledge about the functional mechanisms and development of normal face processing. Here we compared facial identity and facial expression processing in a large, online study with 128 prosopagnosics and 128 sex/age-matched controls. We used three experimental tasks of sorting, simultaneous matching, and sequential matching to assess facial identity and facial expression processing within the same format. Pilot data ensure all tasks were sensitive for detecting subtle deficits, were equally difficult across identity and expression versions, and produced sizeable inversion effects characteristic of face processing. Our main findings are twofold. First, prosopagnosics performed worse with facial identity than with facial expression, and they showed reduced inversion effects for facial identity but normal inversion effects for facial expression. Second, prosopagnosics showed subtle deficits for facial expression, but these deficits can be accounted for by their scores on a measure of subthreshold autism trait. These results provide strong evidence for a dissociation between facial identity and facial expression processing in developmental prosopagnosia that is qualitative, not quantitative, in nature. They also suggest that the core deficit in developmental prosopagnosia is specific to facial identity rather than generic to all aspects of face processing. Finally, our findings imply that facial identity and facial expression processing rely on functionally separate mechanisms that dissociate in development.

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53.315 **The scan-paths of acquired and developmental prosopagnosic subjects during a face memorization task** Dong-Ho Lee[1](dongho.m.lee@gmail.com), Sherryse Corrow[1,2], Jason JS Barton[1]; [1]Human Vision and Eye Movement Laboratory, Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, Psychology, University of British Columbia, Vancouver, Canada, [2]Department of Psychology, Bethel University, Minneapolis, USA

Introduction: The location and sequence of visual fixations can reveal internal estimates of the most informative locations to fixate and the efficiency of perceptual processing at those fixations. Therefore scanpaths can help evaluate subjects with impaired perceptual processing. In prosopagnosia – the impaired ability to recognize faces – there are apperceptive and amnestic variants, linked to occipito-temporal and anterior-temporal lesions respectively, as well as a developmental form. How these variants differ in scanning faces is not well known. Our goal was to compare their scanpaths with the hypothesis that the apperceptive variants would have more abnormalities in scanning behaviour than the amnestic variants. We also assessed a cohort with developmental prosopagnosia to determine if their behaviour resembled the apperceptive or the amnestic variants. Methods: We tracked the visual fixations of 20 control subjects, 8 developmental prosopagnosics, and 8 acquired prosopagnosics (4 apperceptive and 4 amnestic), as they memorized faces. We analyzed their scanpaths with a region of interest analysis, recurrence quantification analysis (RQA) and a ScanMatch analysis. Results: Subjects with the apperceptive variant showed an anomalous preference to fixate the periphery of faces ($p< 0.05$) compared to the three other groups. They also showed a trend of higher laminarity ($p< 0.055$) and entropy ($p< 0.055$) in the RQA suggestive of looking at facial features in more detail and in a more chaotic pattern than controls. The ScanMatch analysis showed that all groups except for the apperceptive variant had sequences of fixations which were more similar when looking at faces of the same identity versus different identities

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(p< 0.05). Conclusion: Subjects with apperceptive prosopagnosia from occipito-temporal lesions show anomalous scanning that suggests more difficulty processing and using internal features during a face-memorizing task. In contrast, subjects with an amnestic variant and those with the developmental form show more normal scanning behaviour.

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53.316 **Neural origins of cuteness perception and caregiving motivation: evidence from developmental and acquired prosopagnosia** Edwin J Burns[1](eburns@ntu.edu.sg), Ebony Murray[2], Rachel Bennetts[2], Sarah Bate[2], Alice HD Chan[3], Hong Xu[1]; [1]Psychology, School of Social Sciences, Nanyang Technological University, Singapore, [2]Department of Psychology, Bournemouth University, UK, [3]Linguistics and Multilingual Studies, School of Humanities, Nanyang Technological University, Singapore

Cuteness is an intrinsic quality conveyed by infant faces that elicits strong nurturing desires in the viewer. Where these perceptions of cuteness first arise in the brain are, however, still the matter of some debate. Individuals with developmental prosopagnosia suffer lifelong impairments in face recognition due to atypicalities associated with their fusiform gyrus. If the fusiform gyrus has a key role to play in cuteness perception and the elicitation of a caregiving response, then we would expect these cases to also suffer abnormalities in these behaviours. We tested this hypothesis by asking a group of developmental prosopagnosia cases and matched controls to rate the cuteness of, and their desire to provide care to, a range of infant and adult human and animal faces. As anticipated, the prosopagnosia cases were reduced in their perceptions of infant cuteness and reported a lower desire to give care for the human baby faces. Further testing of an acquired prosopagnosia case that had lesions encompassing his fusiform gyrus replicated these atypicalities in cuteness perception and caregiving. The fusiform gyrus is therefore the likely neural origin of our perceptions of cuteness, which in turn activates subsequent brain regions involved in complex, altruistic behaviours. Due to lower parental motivations typically being associated with poorer quality parent-infant interactions, we predict our findings will have serious clinical implications for those with prosopagnosia and their children.

53.317 **Reduced Perceptual Narrowing in Autism: Evidence from the Other-Race Face Effects** Sivan Schwartz[1](ssivi90@gmail.com), Batsheva Hadad[1]; [1]Department of Special Education and Edmond J. Safra Brain Research Center, University of Haifa

Over the course of development, the perceptual system becomes more efficient and specialized for the stimuli at hand in its close environment. This perceptual narrowing is a fundamental process, already emerging in infancy for several types of stimulation, such as faces, music, and language. For example, processing faces from one's own race has an advantage over faces from other races. Despite the adaptive value of this narrowing in perception, recent evidence suggests it is generally reduced in individuals with ASD. The findings, however, are inconsistent, especially for faces. We examined perceptual narrowing in autism, testing qualitative and quantitative changes in the other-race effects (ORE). Participants (24 TD and 19 high-functioning ASD) were simultaneously presented with two faces and asked to indicate whether the two faces were same or different. Within each race, morphed faces were created to manipulate discrimination difficulty, and orientation was manipulated to examine inversion effects. The results for the upright faces showed that although ORE was exhibited for both groups, it was smaller for the ASD group, resulting specifically from the reduced specialization to the own-race faces in that group. Comparing inversion effects for the two race-faces revealed that while the inversion effect was bigger for the Caucasian faces in the TD group, there were no such differences in the sensitivity to orientation between the two races in the ASD group. Furthermore, contrary to prevailing views, individuals with ASD showed an overall lower sensitivity in perceptual discrimination of faces and an overall reduced inversion effect, suggesting both qualitative and quantitative differences in face perception between the two groups. These findings indicate that the perceptual system in autism does not become specialized to the more frequently encountered faces, at least not to the same extent as in TD individuals, suggesting less tuned, non-specific face representations.

53.318 **Higher levels of autistic traits are linked to poorer face recognition performance but not reduced adaptive coding in 6-8 year-old children** Linda R Jeffery[1,2](linda.jeffery@uwa.edu.au), Kate Crookes[1,2], Ellen Bothe[1,2], Marianne Thorburn[2], Natalie Kaiko[1,2], Chloe Giffard[1,2], Romina Palermo[1,2]; [1]ARC Centre of Excellence in Cognition and its Disorders, [2]School of Psychological Science, The University of Western Australia

The ability to recognise people from their faces is very important for successful social interaction. Recognition of faces is impaired in individuals with autism and is also poorer in typical adults who report higher-levels of autistic traits on self-report questionnaires, such as the Autism Quotient (AQ). Likewise, adaptive, norm-based coding, a perceptual mechanism important for face recognition, is also attenuated in individuals with autism and typical male adults with higher autistic-traits. Here we asked whether associations between autistic traits and face recognition and adaptive coding are also present during development, when social experience is accumulating and performance on face tasks is improving. We tested 6-8 year-old children (N=163, 77 males) on a battery of tasks. Face memory was assessed with the Cambridge Face Memory Test–Kids and Dartmouth Face Perception Test and the Cambridge Bicycle Memory Test was included to calculate 'face-selective' residuals. Adaptive coding was measured with a face identity aftereffect task and the AQ-Child measured parent-reported autistic traits. Children who scored higher on the AQ-Child had poorer face-selective memory performance, after controlling for age and sex. The direction of the associations did not differ for boys and girls, though the association between autistic-traits and face-selective memory was significant only for boys. Neither adaptive coding or face-selective perception were associated with autistic traits. These results suggest that the association between autistic traits and face recognition ability emerges early in development, consistent with findings that children with autism have impaired face recognition skills. However, we found no evidence that weaker adaptive norm-based coding mediates this relationship in children, even for boys, suggesting that the relationship between autistic-traits and adaptive coding emerges later in development. Likewise, sex differences in the associations between face recognition, adaptive norm-based coding and autistic-traits may also emerge only later in development, possibly during adolescence.

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53.319 **Effect of the noxious stimuli used on empathy-related activations in people with and without Autism Spectrum Disorder (ASD)** Amandine Lassalle[1, 2](alassalle@mgh.harvard.edu), Nicole R Zürcher[1], Loyse Hippolyte[3], Eva Billstedt [4], Carlo A Porro [5], Francesca Benuzzi [5], Patricia Solomon[6], Kenneth M Prkachin[7], Eric Lemonnier[8], Christopher Gillberg[4], Jakob A Johnels[4, 9], Nouchine Hadjikhani[1, 4]; [1]MGH/ Martinos Center for Biomedical Imaging/ Harvard Medical School, Boston, USA, [2]Department of Psychology, University of Amsterdam, Amsterdam, The Netherlands, [3]Service de Génétique Médicale, University of Lausanne, Lausanne, Switzerland, [4]Gillberg Neuropsychiatry Center, Gothenburg University, 41119 Gothenburg, Sweden, [5]Department of Biomedical, Metabolic and Neural Sciences, University of Modena and Reggio Emilia, Modena, Italy, [6]School of Rehabilitation Science, McMaster University, Hamilton, Ontario, Canada, [7]Health Psychology Laboratory, University of Northern British Columbia, Prince George, British Columbia, Canada, [8]Centre Hospitalier Universitaire de Limoges, France, [9]Section for Speech and Language Pathology, Gothenburg University, 41119 Gothenburg, Sweden

The extent to which affective empathy is impaired in Autism Spectrum Disorder (ASD) remains unclear, as some -but not all - previous neuroimaging studies investigating empathy for pain in ASD have shown similar levels to those of neurotypicals individuals. These inconsistent results could be due to the use of different empathy-eliciting stimuli. While some studies used pictures of faces exhibiting a painful expression, others used pictures of limbs in painful situation. In the present study, we used fMRI to compare activation in the empathy network for these two types of stimuli in 31 participants (16 with ASD). We computed brain activity at the whole brain level and in regions of interest within the empathy network. In accordance with the results of previous studies, we found a group difference in the empathy network (particularly the inferior frontal gyrus [IFG] and thalamus) when participants viewed stimuli of limbs in painful situations, but not when they viewed face stimuli with a painful expression. In addition, we found that both groups of participants activated their empathy network more when viewing pictures of limbs in painful situation than when viewing pictures of faces with a painful expression. However, this increased activation for limbs vs. faces was significantly enhanced in controls relative to ASD participants, especially in the secondary somatosensory cortex (SII). Although caution should be used interpreting our findings (different tasks were used for the face and limb stimuli), they suggest that empathy defect of people with ASD is contingent upon the type of stimuli used, and may be related to the level of Mirror Neuron System (MNS) involvement, as the brain regions showing a group difference (IFG, SII) underlie embodiment. We discuss the potential clinical implications of our findings in terms of developing interventions boosting the empathetic abilities of people with ASD.

53.320 **Individuals with Autism Spectrum Disorder utilize local viewing strategies for facial identity discrimination: an eye tracking study** Kirsty Ainsworth[1](kirsty.ainsworth@mcgill.ca), Domenico Tullo[1], Massimo Pietracupa[1], Jacalyn Guy[2], Armando Bertone[1]; [1]Perceptual Neuroscience Lab (PNLab) for Autism and Development, McGill University, [2]ABCD laboratory, Department of Experimental Psychology, University of Oxford

Atypical face perception in "high-functioning" individuals with Autism Spectrum Disorder (ASD) is either interpreted as a consequence of socio-communicative behaviours (Schultz, 2005), or resulting from abnormally local/detailed perceptual strategies (Behrmann et al., 2006). This is exemplified by a decreased ability to discriminate facial identities when access to local facial cues is minimized (e.g. Morin et al., 2015). We aimed to assess if global or local perceptual strategies were used by individuals with ASD with below average IQ during a face identity discrimination task. Nineteen individuals with ASD (17 male, 2 female) and below average IQ (WASIFSIQ=81) were presented with synthetic face stimulus pairs (Wilson et al, 2002) that were both front-facing (same-view condition), allowing for local identity judgements (e.g., comparing noses), or front-side facing (view-change condition) with one face oriented front and the other side facing (20 deg.). The view-change condition decreased access to local information, resulting in greater reliance on a global analysis to complete the task. Participants were asked to answer 'same' or 'different' during face pair presentation; eye fixation data were collected during task completion. Percentage of time spent looking at each region of interest was calculated. Although there was no main effect of view condition ($p=0.76$), a main effect of region of interest was found ($p< 0.001$). The eyes and the hairline were viewed significantly more than the nose, mouth and hairline for both front-front (local; $p< 0.001$), and front-side (global; $p< 0.001$) conditions. Hence, these results indicate a pattern of viewing that isolates specific areas of the face (i.e., local processing) as opposed to rapid use of several regions to create a perceptual 'whole' (i.e., global processing) in individuals with ASD. By isolating local and global processing in synthetic faces, this study demonstrates that individuals with ASD with below average IQ prefer local processing strategies.

53.321 **Reduced sensitivity to static and dynamic eye gaze cues in adolescents with autism** Jason W Griffin[1](jxg569@psu.edu), K. Suzanne Scherf[1]; [1]Department of Psychology, The Pennsylvania State University

Hallmark features of autism include atypical eye contact and visual attention to faces. These atypicalities have been quantified using eye tracking in high-risk infants and individuals diagnosed with autism. However, what is less clear is whether and how these atypicalities have functional consequences for behavior. In this project, we investigated the possibility that even subtle impairments in the ability to detect gaze trajectories interfere with the ability to understand the potential intentions of an actor. We designed two tasks to gauge participants' sensitivity to eye gaze trajectory. In both tasks, an actor was surrounded by many objects and directed their gaze to a single object. In the static version of the task, this information was presented to participants within a photograph. In the dynamic version of the task, a woman was filmed looking at the camera, then saccading to the target gazed-at object, and looking back at the camera. In both tasks, participants had to pick the target gazed-at object from a list of 4 labels, which also included the labels for the nearby plausible non-target and two non-plausible objects. In order to perform the task successfully, participants had to precisely compute the gaze trajectory information to identify the gazed-at object and rule out the plausible non-target object. We tested adolescents with autism and age- and IQ-matched typically developing (TD) adolescents in both tasks. We also collected eye tracking data. Indeed, the adolescents with autism exhibited worse performance (by more than 10%) than the TD adolescents on both tasks, with an emerging pattern of more severe deficits on the dynamic task. Our findings suggest that this reduced sensitivity to detect and compute eye gaze trajectories in adolescents with autism may interfere with the ability to understanding and/or anticipate how a person intends to act on the world of objects.

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53.322 **Coarse information drives confusion of perceived emotion in schizophrenia** Simon Faghel-Soubeyrand[1](simon-soubeyrand@gmail.com), Tania Lecomte[1], Antoine Pennou[1], Frédéric Gosselin[1]; [1]Department of Psychology, Université de Montréal

It is widely accepted that emotion processing is impaired in schizophrenic patients (SPs). It is also believed —although evidence to support this claim remain scarce— that SPs confuse (i.e. mis-categorize) some emotions more than healthy individuals. While previous work using the Bubbles technique (e.g. Lee et al., 2011) has revealed aberrant use of facial information that agrees with emotion processing deficit in SPs, their use of only two facial expressions made it difficult to study the sources of the confusions. Here, we examined this question using Bubbles in a four-facial-expression identification task (happy, fearful, angry, or neutral). We first mapped which parts of the face at different spatial scales were used by SPs, and confirmed and extended previous findings. Second, we computed a confusion matrix over the ~13,000 trials completed by all SPs (N=13). Four mis-categorizations had a proportion of responses significantly higher than what is expected by chance (all chi2>60, Bonferroni-corrected ps< .001), including angry faces confused for neutral faces and fearful faces confused for angry faces. Finally, we revealed the specific facial information that drove SPs to commit these two confusions. We discovered that low-spatial frequency (LSF, i.e. coarse information < 10 cycles per faces) from the mouth area and nose area (i.e. philtrum, nose and nasolabial folds), respectively, led to angry faces being mistaken for neutral faces and to fearful faces being mistaken for angry faces. Previous studies revealed magnocellular system abnormalities in the form of below average LSF sensitivity in SPs (Butler et al., 2009). Our results indicate that the inability to extract useful coarse spatial information from expressive faces underlies the mis-labeling of perceived emotions in SPs.

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53.324 **Visual agnosic people don´t optimize the use of relevant piecemeal information when they see new faces** Ela I Olivares[1](ela.olivares@uam.es), Ana S Urraca[2], Jaime Iglesias[1]; [1]Faculty of Psychology. Universidad Autónoma de Madrid, [2]Centro Universitario Cardenal Cisneros, Universidad de Alcalá de Henares

This ERP study analyzes how certain facial features are integrated in order to create new face recognition units and, in particular, how visual agnosic individuals use "diagnostic" information to that end when they meet new faces. Our participants (2 prosopagnosic adults and 8 age-matched controls) carried out a face-feature matching task. In this task both external (E) and internal (I) facial features were presented in a sequence, followed by a complete unfamiliar face that could be an exact (congruent) combination or not (incongruent) of such features. We used two different sequences of features: in the E-I sequence the external features were displayed as the first stimuli in each trial while in the I-E sequence the internal features were the first to be displayed. Similarly to that found in younger people in a previous experiment, our controls exhibited an enhanced mismatch effect around 300-500 ms in the E-I sequence, suggesting a more efficient integration of piecemeal information at the beginning of the trial to create new face representations. Our acquired prosopagnosic also showed a larger mismatch effect in the E-I sequence

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but smaller, more anterior and right-sided than controls, suggesting the use of a different neural circuitry to solve the task. In turn, our developmental prosopagnosic showed a mismatch effect only in the I-E sequence, which was larger and left-sided when compared with healthy controls, suggestive of a predominant use of analytical strategies in unfamiliar face processing. Moreover, the lack of an expected P3 component evoked by features at the beginning of the trial in both patients indicates that task-relevant information is not optimally processed and kept in short-term memory to solve the matching. Thus, modulations in both amplitude and topography of long-latency ERPs concerning structural incongruences might constitute neural markers of cognitive dysfunctions associated to face processing.

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53.325 **Investigating the recognition of static and dynamic facial expressions of emotion in MCI patients** Anne-Raphaelle Richoz[1](anne-raphaelle.richoz@unifr.ch), Junpeng Lao[1], Martino Ceroni[1], Leonardo Sacco[2], Riccardo Pignatti[2], Roberto Caldara[1]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg, Fribourg, Switzerland, [2]Ospedale Regionale di Lugano, Servizio di Neurologia, Switzerland

Unlike static images of facial expressions routinely used in most experiments, natural expressions unfold over time, providing observers with richer and ecologically more valid signals. Our previous findings revealed greater recognition accuracy for dynamic expressions in young and elderly populations (Richoz et al., 2017), an advantage driven by a suboptimal performance for static images in older adults. Interestingly, it has also been shown that patients suffering from mild cognitive impairment (MCI) are impaired for the recognition of static facial expressions. Yet, the very nature of such a deficit and its presence for dynamic faces remains to be clarified. To this aim, we tested a group of MCI patients and an age-matched healthy control group while they performed a facial expression recognition (FER) task of the six basic expressions in three conditions: static, shuffled (temporally randomized frames) and dynamic (Gold et al., 2013). We observed greater and comparable FER accuracy for dynamic vs. static expressions in MCI patients and the controls. Crucially, however, the MCI patients were significantly more impaired in the decoding of the static expressions of fear, disgust and anger compared to the controls. While static faces may be more sensitive to detect expression recognition deficits in MCI patients, the results obtained in the dynamic condition suggest that their FER ability in their daily life is spared. The deficit in the MCI patients might thus selectively relate to a suboptimal functioning of the ventral face-selective network, which is dedicated to static face processing, while dynamic face processing involves a diffuse network of brain regions. Altogether, these findings not only underline the critical importance of assessing FER with dynamic faces in clinical populations, but also pave the way for the development of future diagnostic tools that may link FER deficits with static images to specific facets of cognitive decline.

53.326 **Are you looking at me? The effects of hemianopia on perception of mutual gaze** Alex R Bowers[1](alex_bowers@meei.harvard.edu), Sarah S Sheldon[2], Heiko Hecht[3]; [1]Schepens Eye Research Institute, Harvard Medical School, [2]Department of Psychology, University of Alberta, [3]Psychologisches Institut, Johannes Gutenberg-Universität Mainz

Perception of mutual gaze direction is an important, nonverbal communication cue in social interactions. Individuals with hemianopia (without neglect) often show a visuo-spatial bias towards the side of the hemifield loss in perceptual tasks. We investigated whether such biases also manifest in judgements of mutual gaze direction. Participants adjusted the eye position of a life-size virtual head on a monitor at a 1-m distance until (1) the eyes appeared to be looking straight at them; or (2) the eyes were perceived to be no longer looking at them (to the right and left), providing a measure of the gaze cone width (the range of gaze directions that are perceived as 'being looked at'). Contrary to expectations, neither participants with left hemianopia ($n = 10$) nor right hemianopia ($n = 10$) differed from age-similar, normally-sighted controls ($n = 22$) in their judgments of straight ahead gaze direction ($p = 0.34$). Gaze cone widths also did not differ between hemianopes and controls ($p = 0.30$). However, hemianopes' judgments were more variable than those of controls, especially when gaze of the virtual head was directed toward their blind hemifield ($p = 0.01$). Interestingly, four participants with left hemianopia and neglect history (not included in the main analyses) demonstrated a rightward shift in their perception of gaze direction and had an asymmetric gaze cone (wider on the blind side), although the overall width was similar to that of participants without neglect history. In summary, participants with hemianopia without neglect history did not show any spatial biases in gaze judgements, although biases were present on a line bisection task. However, residual neglect, not detected on traditional pencil and paper tests, appears to manifest in simulations of more real world tasks, as reported for collision judgments in a simulated walking task (Houston et al., 2015).

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Faces: Individual differences

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53.327 **Assessing the reliability of neural face discrimination with fast periodic visual stimulation** Lisa Stacchi[1](lisa.stacchi@unifr.ch), Meike Ramon[1], Joan Liu-Shuang[2], Roberto Caldara[1]; [1]Eye and Brain Mapping Laboratory (iBMLab), Department of Psychology, University of Fribourg,Switzerland, [2]IPSY & IONS, University of Louvain, Belgium

Over the past years, fast periodic visual stimulation (FPVS) has been used extensively as an objective measure of neural face discrimination. Xu et al. (2017) reported that the pattern of individual differences of this measure was observed consistently across four trials assessed in the same testing session. Independently, we reported that the amplitude and topography of this neural response is differentially modulated across observers as a function of the foveally presented facial information (i.e., viewing position; VP) (Stacchi et al., 2017). Nevertheless, whether the reliability of neural face discrimination responses varies across VPs between and within subjects has yet to be clarified. We recorded high-density electrophysiological signals in 14 subjects during FPVS with a test-retest design (6-month inter-session interval). On each trial, fixations were enforced on the center of the screen and faces were realigned to one of 10 VPs, covering all inner facial features. The FPVS face discrimination response reliability was computed for 44 posterior electrodes using Cronbach's alpha on the group amplitude and individual topographies. At the group level, reliability of the FPVS response amplitude aggregated across posterior electrodes was generally stable for all VPs. Interestingly, intra- and inter-subject differences emerged for the reliability of the topographies, which varied at the individual level. While some subjects showed highly reliable FPVS face discrimination responses across all VPs, others were extremely unstable; the majority showed reliable responses only for specific VPs. Crucially, the reliability of the FPVS face discrimination response topography was directly correlated with the overall amplitude. Our findings invite to careful consideration of individual differences according to their reliability, as those that are expressed more consistently could be functionally more meaningful. Moreover, our observations suggest that the magnitude of the neural face discrimination responses is an effective indicator of response reliability.

53.328 **Individual differences in face identification correlate with face detection ability** Virginie Burns[1](burv02@uqo.ca), Guillaume Lalonde-Beaudoin[1], Justin Duncan[1,2], Stéphanie Bouchard[1], Caroline Blais[1], Daniel Fiset[1]; [1]Département de Psychoéducation et de Psychologie, Université du Québec en Outaouais, [2]Département de Psychologie, Université du Québec à Montréal

Our brain is tuned to detect, identify and integrate social information conveyed by faces. Despite the crucial role of face detection, little is known about the visual processes underlying this endeavor and how it is related to face identification. Recently, Xu and Biederman (2014) presented a case of acquired prosopagnosia with a face-specific detection impairment. Compared with controls, MJH needs significantly more visual signal for face detection, but not for car detection. Thus, we hypothesized that there may exist a correlation between face identification and detection proficiency in normal adults. Forty-five participants (24 women) performed the Cambridge Face Memory Test (CFMT; Duchaine, & Nakayama, 2006), the Cambridge Face Perception Test (CFPT; Duchaine, Germine, &

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Nakayama, 2007), and the Glasgow Face Memory Test (GFMT; Burton, White, & McNeil, 2010). They also completed two detection tasks : a face detection task and a car detection task. The power spectra were equalized across face and car stimuli. Individual face identification abilities were calculated by computing a weighted average of CFMT, GFMT, and CFPT scores (the latter of which was negatively scored). Face and car detection abilities were reflected by their respective detection thresholds, defined as phase spectrum coherence (as per Xu and Biederman, 2014). We observed a negative correlation between face identification ability scores and face detection thresholds (r = -.47 p< .01), which remained significant when computing the Spearman correlation (rs = -.42, p< .01). The correlation also remained significant when controlling for car detection ability (r = -.371, p< .05). Our results suggest that face detection and face identification share some perceptual or cognitive resources. More research will be needed to better understand what exactly is shared between these two tasks.

Acknowledgement: NSERC

53.329 **The relation between facial recognition response time and facial recognition ability: task demands modulate its direction and magnitude** Joseph Arizpe[1,2](Joseph_Arizpe@hms.harvard.edu), Elyana Saad[1,2], Jeremy B Wilmer[3], Joe M DeGutis[1,2]; [1]Psychiatry Department, Harvard Medical School, [2]VA Boston Heathcare System, [3]Psychology Department, Wellesley College

There is growing interest in using reaction time (RT) during recognition tasks as an index of face (or object) recognition ability. However, whether RTs are valid in this context and whether they explain recognition ability variance above and beyond accuracy alone has not yet been established. Decades of individual differences research in other domains, particularly in intelligence testing, consistently shows that faster RTs on very simple RT tasks are predictive of greater cognitive ability. This robust association has yet to be accounted for theoretically and further, it is not clear whether this association holds when using RTs from more complex tasks. To better characterize the RT/ability relationship during simple and complex tasks, the present study (N=2,627 participants) examined the associations of RTs on the simpler vs. more cognitively demanding stages of the Cambridge Face Memory Test (CFMT) with face recognition ability as independently defined by Famous Faces Memory Test (FFMT) score. We found that CFMT section RTs explained ~5% additional variance in FFMT score beyond CFMT section accuracies. Importantly, the direction and presence of the correlation between CFMT RTs and FFMT scores differed by CFMT section. Specifically, RTs from the simpler, delayed-match-to-sample section negatively correlated with FFMT ability level. RTs from the intermediate section did not correlate with ability level despite our massive sample, but RTs from the most demanding section, involving recognizing multiple faces from foils in visual noise, positively correlated with ability. CFMT trial accuracies indicated that waning motivation for lowest ability participants did not account for this shift. These results reveal that task RTs may be useful as an index of face recognition ability, and, more generally, suggest that faster RTs do not universally predict greater cognitive ability. Rather, task demands can modulate the direction and magnitude of the relationship between RT and cognitive ability.

53.330 **Task-specific extraction of horizontal information in faces** Gabrielle Dugas[1](dugg06@uqo.ca), Jessica Royer[1], Justin Duncan[1, 2], Caroline Blais[1], Daniel Fiset[1]; [1]Université du Québec en Outaouais, [2]Université du Québec à Montréal

Horizontal information is crucial for accurate face processing (Goffaux & Dakin, 2010). Individual differences in horizontal tuning were shown to correlate with aptitude levels in both face identification (Pachai, Sekuler & Bennett, 2013) and facial expression categorization (Duncan et al., 2017).These results thus indicate that the same visual information correlates with abilities in two different face processing tasks. Here, we intended to verify if the ability to extract horizontal information generalizes from one task to the other at the individual level. To do this, we asked 28 participants to complete both a 10-AFC face identification task and a race categorization (Caucasian vs. African-American) task (600 trials per task). To find out which parts of the orientation spectrum were associated with accuracy, images were randomly filtered with orientation bubbles (Duncan et al., 2017). We then performed, for each subject, what amounts to a multiple linear regression of orientation sampling vectors (independent variable) on response accuracy scores (dependent variable). A group classification vector (CV) was created by first summing individually z-scored CVs across subjects, and then dividing the outcome by √n, where n is the sample size. These analyses, performed separately for each task, show that horizontal information is highly diagnostic for both face identification (Zmax = 24.8) and race categorization (Zmax = 22.9), all ps < .05 and Group CVs of both task were highly correlated, r= .96, p< .001, showing high similarity in visual strategies at the group level. At the individual level, however, horizontal tuning measures (as per Duncan et al., 2017) in the identification and race categorization tasks did not correlate, r = -0.02, ns. Our results thus show that, although horizontal information is diagnostic for both tasks, individual differences in the extraction of this information appears to be task dependent.

Acknowledgement: Natural Sciences and Engineering Research Council

53.331 **Matching Depth-Rotated Faces at Varying Degrees of Physical Similarity** Tianyi Zhu[1](zhu990@usc.edu), Miles Nelken[2], Catrina M. Hacker [2], Emily X. Meschke[3], Irving Biederman [1,2]; [1]Department of Psychology, University of Southern California, [2]Program in Neuroscience, University of Southern California, [3]Program in Computational Neuroscience, University of Southern California

There is a clear perceptual component to Congenital Prosopagnosia (CP). Given a triangular array of three faces in a minimal match-to-sample test (Fig. 1), those who have difficulty in matching which of the two highly similar lower (test) faces is an exact match to the upper face (the sample), also score at the prosopagnosia end on all the standard tests of face recognition proficiency, such as the CFMT. But there is another perceptual component to face perception: invariance to viewpoint. Is it the case that those who have greater difficulty in discriminating small metric variations of faces at the same orientation, also have greater difficulty in matching faces when their orientations in depth differ? (Fig. 1, right panel.) Subjects discriminated triangular arrays of either three faces or three geons, one of which was an exact match to the sample (Fig. 1). Sample and matching stimuli could be at the same orientation in depth or differ by 13°. The underlying differences in the stimuli were metric variations of the spacing between face parts and cheekbone height. Geons varied in the curvature of the axis or convergence of the sides. Dissimilarity of the foil to the matching stimulus was equated by Gabor similarity for faces and geons. Across subjects (n=14), RTs at a 0° difference in face orientations correlated positively with the increase in RTs at a 13° orientation difference, indicating that those who have difficulty in identifying subtle differences in the physical appearance of faces all at the same orientation, demonstrate less invariance at identifying faces at different orientations (Fig. 2). Importantly, this effect was only present for the faces, not for the geons. These deficits in discriminating faces thus do not reflect a general deficit in discriminating metric differences between stimuli.

Acknowledgement: Dornsife Foundation, NSF

53.332 **Still Rough Around the Edges – Effects of Age and Individual Differences on Neural Network Organization in Young Adults** Daniel Elbich[1,2](dbe5007@psu.edu), Suzy Scherf[1,2]; [1]The Pennsylvania State University, [2]Social, Life, and Engineering Sciences Imaging Center

Researchers tend to think of adults as face recognition experts, given the more than 10 years of experience honing this skill. However, recent evidence indicates that there is a vast range of individual differences in face recognition abilities even among typically developing young adults. Importantly, the vast majority of work on face recognition abilities is done with participants who are emerging adults, who are ages 18-25 years, when face recognition skills are still developing (see Germine et al., 2011). In this presentation, I will describe findings from functional and diffusion neuroimaging experiments (all conducted with the same participants) that reveal how age and individual differences in performance relate to variations in underlying neural network organization for face processing. A group of 40 emerging adults completed tasks of both unfamiliar and familiar face recognition outside the scanner that are reliable tools for measuring individual differences in recognition performance (see Elbich & Scherf, 2017). These participants were then scanned using fMRI, as they passively viewed faces and other visual categories, and diffusion MRI. We report that when controlling for the age-related effects in behavior, we

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still observed individual differences in behavior that were significantly related to functional neural network organization. Specifically, better recognizers exhibited a larger proportion of activated nodes in the face processing network and distinct patterns of directed functional connections among these nodes. In addition, the results from the dMRI study revealed some age-related declines in diffusivity in the long-range fiber tracts that connect face processing regions (ILF, IFOF) as well as age-independent associations between better recognition behavior and decreasing diffusivity. Together, these findings reveal that performance differences in face recognition among emerging adults are related to both ongoing age-related changes as well as individual differences in neural network organization.

53.333 **How holistic processing of faces relates to cognitive control and intelligence** Isabel Gauthier[1](isabel.gauthier@vanderbilt.edu), Kao-Wei Chua[2], Jennifer J Richler[1]; [1]Psychology Department, Vanderbilt University, [2]Psychology Department, New York University

The Vanderbilt Holistic Processing Test for faces (VHPT-F) was designed to measure individual differences in holistic processing. The test measures failures of selective attention to face parts, an operational definition of holistic processing that has been challenged by the suggestion that it may tap more general control mechanisms that yield congruency effects in Stroop and Flanker paradigms. We explore the relations between holistic processing of faces and measures of cognitive control that are also operationalized using congruency effects. Because other work finds a relation between intelligence and selection processes that are either lower level (motion perception) or higher level (working memory) than holistic processing of faces, we also measured intelligence. We report data from 130 subjects on the VHPT-F, several Stroop and Flanker tasks, and measures of fluid IQ. Five of our six Stroop and flanker tasks provided minimally reliable congruency effects in accuracy, but not in response times. We found non-negligible shared variance among these cognitive control tasks, in zero-order correlations and in a principal component analysis. Neither of these analyses suggested any shared variance between the congruency effects in the VHPT-F and measures of cognitive control. Zero-order correlations. The PCA on accuracy in each individual condition grouped performance in the VHPT-F task with accuracy in flanker tasks, more than that in Stroop tasks. This is consistent with the idea that holistic processing depends on attention-dependent mechanisms that can integrate spatially separated face parts rather than on undifferentiated holistic representations. Variability on the VHPT-F was also not correlated with Fluid IQ. Our results suggest that to the degree that there are control mechanisms common across cognitive control tasks, they do not appear to be responsible for variability in congruency effects in the VHPT-f, despite robust congruency effects in all cases.

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53.334 **I Can Read You Like a Book: Expression Recognition is Positively Correlated with the Fantasy Empathy Subscale.** Cindy Bukach[1](cbukach@richmond.edu), Rebecca Nguyen[1], Tessa Rinnen[1], Pascaline Munezero[1], Peter Kade[1], Ana Deutsch[1]; [1]Department of Psychology, University of Richmond

High empathy is associated with better recognition of facial expressions (Chikovani et al., 2015). Here we investigate what aspects of empathy are related to improvement in expression recognition, and whether empathy also modulates facial identification. Participants completed an expression recognition task in which they viewed dynamic facial stimuli that morphed from neutral to an emotion (happy, sad, angry, or fearful). Participants stopped each morphing video as soon as they could identify the emotion, then completed a 2-alternative forced choice recognition task. Participants also completed an identity recognition task in which they viewed morph videos from an average to an individual model, then were given an 8-alternative forced choice task. Participants also completed the Interpersonal Reactivity Index (IRI) that measures four empathy subscales: perspective taking (adopting the psychological viewpoint of others), fantasy (tendency to imagine the feelings and actions of fictitious characters), empathic concern (other-oriented feelings of sympathy and concern) and personal distress (self-oriented feelings of anxiety). Preliminary results (N=38) indicate that although expression recognition is positively correlated with identification accuracy ($r = .415$, $p = .01$), high levels of empathy were associated with expression but not identity recognition. Specifically, the fantasy and empathic concern subscales were positively correlated with expression recognition accuracy ($r = .391$, $p = .015$ and $r = .341$, $p = .036$ respectively). High scores on these scales improved recognition of fear, happiness, and anger, but not sadness. When entered in a regression model with anxiety and depression scales, only identity recognition accuracy and fantasy subscale significantly predicted expression recognition ($\beta = .385$ and $.359$, p's $= .010$ and $.016$, respectively). These results indicate that empathy affects expression-specific mechanisms. One possible explanation is that empathizing with the feelings of fictional characters and the ability to recognize emotional expressions of strangers both may rely on simulation of facial movements.

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53.335 **The relationship between one's own interoceptive abilities and recognition of others' non-emotional internal state** Rebecca Brewer[1](Rebecca.brewer@rhul.ac.uk), Jennifer McBride[2]; [1]Royal Holloway, University of London, [2]University of East London

Much research has investigated the ability to recognise others' emotions (happiness, fear, anger, etc.) and previous work suggests that the ability to recognise an emotional state in another individual is strongly related to the ability to recognise one's own emotions. No previous work has addressed the ability to recognise non-emotional internal states in others (e.g. temperature, nausea, satiety, fatigue) due to the non-existence of stimulus sets with which to assess this ability. Many individuals with psychological disorders (including Eating Disorders) struggle to perceive their own non-emotional internal states (interoception), making it likely that they would also struggle to recognise these internal states in others. The current study used purposely-developed stimuli depicting actors posing non-emotional internal states (satiety, pain, nausea, cold, fatigue, itch, and breathlessness) in a visual recognition task, in order to assess the ability to recognise others' internal states. 30 typical control participants, and 15 participants with a diagnosis of an eating disorder, took part in a recognition task in which stimulus images were obscured by high frequency visual noise, the level of which was adjusted using an adaptive staircase procedure based on performance. Participants also completed measures of their own interoceptive ability (recognising non-emotional internal states in the self). Results indicated that the ability to recognise one's own non-emotional internal states predicted the ability to recognise others' non-emotional internal states. Recognition ability was not related to eating disorder presence or severity, suggesting that difficulties recognising others' internal states are only present in those with eating disorders when the individual also struggles to recognise their own internal states. These results extend the recent findings suggesting that emotion recognition difficulties in psychological disorders are predicted by the understanding of one's own emotions; seemingly, the same logic applies to the recognition of non-emotional internal states.

53.336 **Size doesn't matter. It's the quality of people's social networks that predicts individual differences in face recognition ability.** Laura M Engfors[1,2](laura.mclaughlinengfors@research.uwa.edu.au), Romina Palermo[1,2], Linda Jeffery[1,2]; [1]ARC Centre of Excellence in Cognition and its Disorders, [2]School of Psychological Science, The University of Western Australia, WA, 6009, Australia

Despite the social importance of face recognition, there are considerable individual differences in people's abilities. The causes of this variation are not well understood. One possible contribution to these differences is variation in people's social experience. This question has been investigated indirectly by examining whether socially interested personality traits that are expected to predict social experience (extraversion-introversion) are linked with better face recognition skills. However, evidence for an association is weak. In the current study, we revisited this question using direct, real-world measures of social experience by estimating both the quantity and quality of participants' social networks. The social networks of 200 people, aged between 18-30 years old, were assessed using measures of the overall size of their social network [the number of people the person has frequent contact with, but are not necessarily important to them (Bickart et al., 2010)] and the quality of their social network [number of enduring, supportive relationships with frequent

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interaction, Norbeck Social Support Questionnaire, 1981)]. Unfamiliar face recognition ability was assessed using the Cambridge Face Memory Test (Duchaine & Nakayama, 2006) and familiar face recognition ability with a famous faces task. We found that the overall size of an individual's social network was not significantly related to either unfamiliar or familiar face recognition ability. However, the quality of an individual's social network was positively related to both unfamiliar and familiar face recognition ability. Overall, these findings suggest that the most important aspect of social experience for face recognition ability is possessing many high quality social relationships. Whereas the overall number of people we have regular contact with was not related to face ability. Our results may suggest that people with richer social support networks have acquired better face recognition skills due to higher quality opportunities to individuate faces over their lifetime.

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53.337 **Eye Movements During Face Viewing Predict Individual Differences in Noisy Audiovisual Speech Perception** Johannes Rennig[1](rennig@bcm.edu), Kira Wegner-Clemens[1], Micael S Beuachamp[1]; [1]Department of Neurosurgery and Core for Advanced MRI, Baylor College of Medicine, Houston TX, USA

Humans use visual speech information from a talker's mouth movements to complement auditory information from the talker's voice. Recently, we discovered individual differences in eye movements during viewing of talking faces: some observers mainly fixate the mouth of the talker, while others mainly fixate the eyes. We tested the hypothesis that mouth-lookers would make better use of visual speech in 34 participants. In experiment 1, participants viewed clear audiovisual syllables. A median split of the eye-tracking data was used to classify participants as mouth-lookers (81% of trial-time spent fixating the mouth) and eye-lookers (45%). In experiment 2, participants repeated noisy auditory sentences presented alone or paired with visual speech. An ANOVA on the number of words accurately repeated showed main effects of condition (higher accuracy for audiovisual than auditory speech, F=234, p=10-15) and group (higher accuracy for mouth-lookers, F=5, p=0.03). Critically, there was a significant interaction, with mouth-lookers showing a greater improvement in accuracy when visual speech was presented (F=7, p=0.01). Given the higher acuity of foveal vision, fixating the talker's mouth might be expected to provide more visual speech information. To assess this possibility, we examined the eye movements made by the participants during experiment 2. Both mouth-lookers and eye-lookers almost exclusively fixated the mouth (94% vs. 92% mouth fixation time, p=0.53) consistent with previous demonstrations that noisy auditory speech drives mouth fixation. The propensity to fixate the mouth of the talker even when it is not necessary (during perception of clear audiovisual speech) is linked to improved perception under noisy conditions in which mouth movements are critical for understanding speech. We speculate that although all humans have extensive experience with talking faces, the additional time that mouth-lookers spend examining the mouth leads to greater expertise in extracting visual speech features.

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Binocular Vision: Rivalry and suppression

Tuesday, May 22, 8:30 am - 12:30 pm, Banyan Breezeway

53.338 **Visual plasticity induced by short-term monocular deprivation recovers without visual input** Seung Hyun Min[1](seung.min@mail.mcgill.ca), Alex S Baldwin[1], Robert F Hess[1]; [1]Department of Ophthalmology, McGill Vision Research, McGill University

Short-term monocular deprivation in adults has been shown to temporarily strengthen the contribution of the patched eye to a fused percept. In adults, the effect of monocular deprivation disappears within 30 minutes after the patch has been taken off (Zhou et al., doi: 10.1155/2017/4780876). Here we investigate whether visual deprivation (sitting in the dark) after patching would preserve the effect of monocular deprivation. We patched six adults with normal vision for two hours with a translucent eyepatch. We used a binocular phase combination task to measure each eye's contribution to a fused percept. For the control condition, subjects performed two rounds of baseline tests, were patched for two hours, then performed post-patching measurements at 0, 3, 6, 12, 24, 48, 60 and 96 minutes after patch removal. For the visual deprivation condition, the subjects sat in darkness after patching with both eyes covered for one hour. Subjects then performed the post-patching tests. Each subject completed two sessions for every condition. There was a significant difference (Wilcoxon Signed-Rank, P< 0.05, Cohen's d = 1.5) in the effect of monocular deprivation between the darkness and control conditions. Subjects recovered from monocular deprivation even when sitting in the dark. This result suggests that recovery from the patching effect does not require visual input.

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53.339 **Comparison of Vergence and Accommodation Responses of Strabismic and Non-strabismic hyperopic, and emmetropic children** Sonisha Neupane[1](neupanes@umail.iu.edu), Yifei Wu[1], Vidhyapriya Sreenivasan[1], Don W Lyon[1], Katie S Connolly[1], T. Rowan Candy[1]; [1]Indiana University School of Optometry

Purpose: Accommodative esotropia is associated with significant hyperopia in childhood. Only about 20% of these hyperopes develop esotropia however. What are the factors differentiating the two groups? In this study, we compared accommodation and vergence behavior of strabismic hyperopic, non strabismic hyperopic and emmetropic children. Methods: Simultaneous Purkinje image tracking and eccentric photorefraction (PlusOptix PowerRefractor) were used to record eye alignment and refractive state of age-matched strabismic hyperopes (N=7, Mean Age: 4.36 years, mean cycloplegic refraction: +6.25 D), non-strabismic hyperopes with no optical correction (N=7, Mean Age: 4.61 years, mean cycloplegic refraction: +3.18 D) and emmetropic children (N=10, Mean Age: 5.53 years, mean cycloplegic refraction: +1.13 D). Subjects viewed naturalistic images at 80 & 33cm distances in monocular and binocular viewing conditions. The mean accommodation and alignment postures at the two distances were determined for each participant and compared across groups. Results: The emmetropic group (E) exhibited typical relationships between accommodation(A) and vergence(V) at these distances in binocular conditions (Change: A = 2.01D±0.57, V = 8.47pd±3.35). The hyperopic groups exhibited a range of behaviors. On average non-strabismics (NS) were similar to the emmetropes even in the absence of optical correction (Change: A = 1.64±0.70D, V = 9.53±1.5pd), while the strabismic group (S) were misaligned for the same demands (Change: A = 1.13±1.94D, V = 4.92±9.66pd),). In monocular conditions, the emmetropes exhibited typical response coupling (mean 4.17pd/D of accommodation), which agreed well with the NS group (mean 5.80pd/D of accommodation). Counter to common expectation, the strabismic group did not all exhibit high coupling ratios (mean 3.82 pd/D of accommodation). Conclusion: Simultaneous measures of accommodation and vergence provide critical information about the conflict between coupled vergence and accommodation responses in hyperopes. The data suggest these individuals display an unexpected range of behaviors from fully typical to decompensated convergent deviation.

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53.340 **Assessing the generalizability of eye dominance across binocular rivalry, onset rivalry, and continuous flash suppression** Yun Ding[1](y.ding1@uu.nl), Marnix Naber[1], Surya Gayet[2], Stefan Van der Stigchel[1], Chris Paffen[1]; [1]Department of Experimental Psychology & Helmholtz Institute, Faculty of Social and Behavioral Sciences, Utrecht University, [2]Donders Institute for Brain, Cognition and Behaviour Donders Centre for Cognition, Radboud University

It is commonly assumed that one eye is dominant over the other eye. Such sighting dominance can for example be determined by using the popular hole-in-the-card test. Here, we investigate if preferred sighting eye dominance is linked to sensory eye dominance in several binocular rivalry tasks. For a total of 31 observers we measured eye dominance in the hole-in-the-card test, and left versus right eye differences in first percept onsets during rivalry, in predominance during ongoing rivalry, and in breakthrough times during continuous flash suppression (CFS). Relationships between differences in eye dominance were assessed using Bayesian statistics. We observed no effect of sighting eye dominance on the binocular rivalry tasks. We observed a correlation of eye dominance between onset and ongoing rivalry, but not with CFS. We conclude that sighting

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eye dominance is different from sensory eye dominance, and that CFS is affected by a different form of eye dominance than onset and ongoing rivalry. Eye dominance seems to be a multifaceted phenomenon, which is differently expressed across interocular conflict tests. We recommend that binocular rivalry studies should not use the hole-in-the-card test or similar sighting dominance tests to determine eye dominance. Instead rivalry studies should add pre-trials of the task at interest to calculate differences between the eyes, if the experimental manipulations require a priori knowledge about eye dominance.

53.341 **A model of the development of anisometropic amblyopia through recruitment of interocular suppression** Samuel Eckmann[1], Lukas Klimmasch[1], Bertram Shi[2], Jochen Triesch[1]; [1]Frankfurt Institute for Advanced Studies FIAS, Frankfurt am Main, Germany, [2]Dept. of Electronic and Computer Engineering, HK University of Science and Technology, Clear Water Bay, Hong Kong

In anisometropia the two eyes have different refractive power, preventing simultaneous focusing with both eyes. When not treated early enough this can lead to amblyopia and a permanent loss of stereopsis. In this case, instead of fusing the information from both eyes, the brain suppresses signals from the central region of one eye. The mechanisms underlying this development are not well understood. To shed light on this question, we propose the first computational model for how this suppression may develop. This model extends an earlier model of the simultaneous development of accommodation and vergence control. That earlier model is formulated in the active efficient coding framework, a recent generalization of classic efficient coding theories to active perception. It describes the simultaneous development of receptive field properties and eye movement control to maximize the system's overall coding efficiency. We extend that earlier model to include interocular suppression by introducing a mechanism where strong responses from monocular neurons suppress the signals from the other eye. In the healthy case without anisometropia, the model learns to accommodate correctly and to perform precise vergence eye movements. In anisometropic cases where the ranges over which the two eyes can focus differ, an amyblopia-like state develops, where one eye is reliably suppressed by the other. This causes receptive fields to become increasingly monocular and to favor the dominant eye. However, by recruiting neurons that retain binocular receptive fields, the system is able to maintain the capacity for vergence control. Interestingly, for one myopic and one hyperopic eye, the model develops monovision, i.e., it learns to focus on objects at close distances with the myopic eye and on objects at far distances with the hyperopic eye. In conclusion, we present the first computational model of how anisometropia may lead to amblyopia by recruiting interocular suppression mechanisms.

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53.342 **Get real: Suppressing the real world from awareness using augmented reality goggles** Uri Korisky[1](uri.korisky@gmail.com), Liad Mudrik[1,2]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

In the last few decades, conscious perception has been studied in healthy subjects by rendering stimuli invisible using different methods. Thus far, these stimuli were presented on screen, and were accordingly limited to words, objects or pictures. We present a method which allows, for the first time, to study the unconscious visual processing of real stimuli in the real world, such as actual objects, human faces, food items etc. We developed a novel variant of Continuous Flash Suppression (CFS), a method that was thus far used to suppress on-screen stimuli from awareness. Our variant, real-life CFS, presents CFS masks on augmented reality goggles, hereby suppressing parts of the subjects' immediate surrounding. Therefore, manipulable, interactable and even animate stimuli can be rendered invisible to the subject. Here, we used real-life CFS to probe the difference between the visual processing of real objects and that of 2D images, and found that real objects emerge into subjects' awareness about a second before their 2D, pictorial counterparts. 3D printed models were then used to further explore the source of this difference. In this talk, we will present the new technique and the possible mechanisms of unconscious processing of real-life objects vs. their 2D pictorial representations.

53.343 **Ocular dominance plasticity in obese subjects can be restored by weight loss** Claudia Lunghi[1,2](clalunghi@gmail.com), Giuseppe Daniele[3], Paola Binda[2,4], Angela Dardano[3], Annamaria Ciccarone[3], Santini Ferruccio[5], Giovanni Ceccarini[5], Laura Giusti[3], Stefano Del Prato[3], Maria Concetta Morrone[2,6]; [1]Laboratoire des systèmes perceptifs, Département d'études cognitives, École normale supérieure, PSL Research University, CNRS, 75005 Paris, France, [2]Department of Translational Research and New Technologies on Medicine and Surgery, University of Pisa, Italy, [3]Section of Metabolic Diseases and Diabetes, Department of Clinical and Experimental Medicine, University of Pisa, Italy, [4]Institute of Neuroscience, National Research Council (CNR), Pisa, Italy, [5]Section of Endocrinology, Department of Clinical and Experimental Medicine, University of Pisa, Pisa, Italy, [6]IRCCS Stella Maris, Calambrone (Pisa), Italy

We have recently shown that the adult visual cortex retains homeostatic plasticity by showing that short-term monocular deprivation shifts ocular dominance in favor of the deprived eye (Lunghi et al, 2011). Emerging research indicates a strong link between energy metabolism and brain function. For example, obesity is associated with cognitive impairment, neurodegeneration, neuroinflammation, impaired memory and learning and reduced hippocampal plasticity (Guillemot-Legris & Muccioli, 2017). Here we asked whether the impact of obesity affects plasticity in the visual cortex. We measured visual plasticity in healthy adult volunteers, normal-weight or obese (N=51, age: 19-55 years; BMI: 19-54.5), testing binocular rivalry between orthogonal gratings (size: 2°, contrast: 50%, SF: 2cpd) before and after 2h of monocular deprivation. In normal-weight subjects (N=20, BMI=21.17±0.5 kg/m2), the plasticity index (ocular dominance shift after monocular deprivation) is equal to 0.12±0.01. However, we found that it declines sharply for BMI>40 (thethreshold for the diagnosis of class III obesity), where ocular dominance did not change after short-term monocular deprivation ($t(16)=0.93$, $p=0.37$) despite normal glucose metabolism and regulation. In addition, across subjects, BMI and the psychophysical plasticity index are strongly negatively correlated (rho=-0.55, $p< 0.001$). In a subset of these severely obese patients (n=11, BMI=45.7±1.6 kg/m2) that underwent bariatric surgery (gastric bypass), we tested visual plasticity at different times for up to six months following surgery. We found that the effect of monocular deprivation on binocular rivalry steadily increased after surgery ($F(3,30)=5.37$, $p=0.004$), indicating that visual plasticity was restored. Six months after surgery, when subjects lost on average 25% of their initial weight (BMI=34.3±1.6 kg/m2), we found a 10-fold increase of the plasticity index, from 0.01±0.03 to 0.1±0.03 ($t(10)=3.3$, $p=0.008$), which approached normal values. These results demonstrate a strong influence of energy metabolism on early sensory plasticity and function, though mechanisms accounting for such association remain to be identified.

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53.344 **Conservative Criterion Explains The Non-Conscious Perception of Facial Expression Under Continuous Flash Suppression** Ali Pournaghdali[1](Apour005@fiu.edu), Bennett L. Schwartz[1]; [1]Department of Psychology, Florida International University

A main question in the scientific study of conscious perception is the nature of the dissociation between conscious and non-conscious perception. That is, it is crucial to use bias-free measures to evaluate perceptual sensitivity and response criterion of participants in the conscious and non-conscious tasks to evaluate this dissociation. The aim of this study is to evaluate sensitivity and criterion of participants, using signal detection methods, in a conscious detection and a non-conscious 2-alternative forced-choice (2AFC) tasks for facial expression perception while employing continuous flash suppression (CFS). We hypothesized that non-conscious perception of facial expression under CFS demonstrates real differences between conscious and non-conscious perception. We predicted that participants' sensitivity in the detection task will be significantly lower than their sensitivity in the 2AFC task. After rendering

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invisible images of faces with different facial expression (fearful vs. neutral) for five hundred milliseconds using CFS, participants judged the presence/absence of the faces with a yes/no detection task and the emotion of faces with the 2AFC task. After acquiring data, we evaluated participants' ability to discriminate signal from noise using d' (an index of sensitivity in signal detection theory) and their criterion for detection and 2AFC task. Our results indicate that there is no significant difference between sensitivity of participants in detection and 2AFC task, but we found higher criterion value for detection compared to 2AFC task. Our results indicate that participants' ability to discriminate signal from noise is diminished for both detection and 2AFC tasks while using CFS. Therefore, non-conscious perception of facial expression with CFS may be the result of a more conservative criterion in the detection task as compared to 2AFC task rather than from dissociable processes. These results provided additional evidence for the importance of using bias-free measures over the accuracy-based methods in visual consciousness research.

53.346 **Dealing with dynamic masks: Interocular image similarity delays access to awareness during continuous flash suppression** Sjoerd Stuit[1](S.M.Stuit@uu.nl), Stefan Van der Stigchel[1]; [1]Experimental Psychology, Utrecht University

Visual awareness is thought to have a limited capacity. Therefore, selection of information for awareness can massively impact how we experience the world. To investigate the relative priority for different images to enter awareness, many scientists have turned to an interocular masking paradigm known as Continuous Flash Suppression (CFS). The benefit of CFS is that it allows a certain level of control over which eye's image is perceived first. Namely, while one eye's image is a dynamic mask, the other eye's static image is suppressed from awareness. Due to the dynamic nature of the mask, the similarity between the two eye's images (Interocular Image Similarity; IIS) is not necessarily the same between trials or images. Such variations in IIS may affect the degree of interocular suppression and interfere with the interpretation of CFS suppression durations. In fact, previous studies using schematic images have indeed shown that suppression is more effective when IIS is higher. However, IIS can be computed in many ways and the predicted influence on CFS suppression durations is not necessarily equivalent over different computations. We first asked if CFS suppression durations for natural images are related to IIS. Results show significant relations between CFS suppression durations across different computations of IIS. To be able to suggest a preferred approach for future CFS studies, we next compared reliability, quantified using a cross validation procedure, between the different indices of IIS. Our results suggest that local-luminance similarity indices are more reliable compared to Fourier amplitude spectrum based similarity indices. Finally, we go on to show that removing the influence of IIS substantially influences the outcome of statistical comparisons of CFS suppression durations for different classes of images. We suggest that removing IIS-based influences on CFS suppression durations should be a standard pre-processing step when analyzing access to awareness results.

53.347 **Tilt illusion affected from invisible surroundings in binocular rivalry; Can interocular grouping occur without awareness?** Yeonghun Seon[1](alino159@gmail.com), Woo Hyun Jung[1]; [1]Psychology, College of Social Science, Chungbuk National University

Tilt illusion is the phenomenon that the perceived orientation of center grating is altered by the presence of surround grating with a different orientation. The main purpose of this study is to test whether interocularly separated surrounds can induce tilt illusion during binocular rivalry. In both eyes, the stimulus was presented in three concentric areas; rivalrous orthogonal gratings were presented in the center area of each eye. In the adjacent repulsion condition, grating with 15˚ and grating with 75˚ were presented in the near-surround and in the far-surround, respectively. In the adjacent attraction condition, 75˚ and 15˚ were respectively presented. The task of participants was to respond whether the orientation of center was tilted toward clockwise or counterclockwise from horizontal or vertical. In the experiment 1, participants were asked to respond only when they perceived a whole stimulus without any piecemeal patches. As expected, a repulsive effect was found in the adjacent repulsion condition. Interestingly, however, in adjacent attraction condition a repulsive effect was found. These results can be interpreted at least two different ways; the influence from the visible far-surround in the same eye or from the invisible near-surround in the opposite eye. In experiment 2, it was examined whether the results of experiment 1 were induced from the invisible near-surround in the opposite eye. The same stimulus presented to left or right eye in experiment 1 was presented to both eyes. The repulsive effect from adjacent attraction condition was smaller than that in experiment 1 under binocular rivalry. The repulsive effect from adjacent repulsion condition was bigger than that in experiment 1 under binocular rivalry. These findings suggest that both repulsive and attractive effect could be induced from invisible rivalrous surroundings in the opposite eye and interocular grouping might be occurred without awareness.

53.348 **Visual awareness requires the integration of higher-level brain regions with the stimulus-selective regions** Tian Xue[1](tx19900109@126.com), Xu Shan[1], Chen Chen[1], Hu Si Yuan[1], Song Yi Ying[1,2], Liu Jia[1]; [1]School of Psychology, Beijing Normal University, [2]State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University

Consciousness is a core aspect of human cognition; however, the neural basis of consciousness remains unclear. It has been shown that activity in the stimulus-selective regions reflects the content of visual awareness, but it is unknown whether there are some high-level regions generally involved in conscious perception irrespective of specific content. Here we used the binocular rivalry paradigm to induce perceptual alteration, in which a face and a house image were presented to different eyes and the conscious perception switched between house and face even when sensory input remained constant. Using functional magnetic resonance imaging, first, we replicated previous finding that the fusiform face area (FFA) activity increased and parahippocampal place area (PPA) activity decreased when perception changed from house to face, and vice versa. Importantly, to explore the regions generally involved in conscious perception irrespective of specific content, we searched for regions coordinate both with the FFA during face perception and with the PPA during house perception. To measure coordination between regions, we defined an index of pattern shift similarity, that is, if two regions cooperated during conscious perception, multivariate pattern changes in one region should be synchronized with those in the other. We found several regions showing higher pattern shift similarity with the FFA when perception changed from house to face and with the PPA when perception changed from face to house, including the intraparietal sulcus (IPS), precuneus and inferior frontal gyrus (IFG). This result applied only to the rivalry condition, but not to the non-rivalry condition when the stimulus alternated between presentation of either face or house alone according to the temporal sequences the subjects reported in the rivalry condition. These results suggested that visual awareness required cooperation between high-level regions generally involved in conscious perception and the stimulus-selective regions reflecting the specific content of conscious perception.

53.349 **The Processing Status of Binocular Rivalry without Attention** Stella C Qian[1](qianche5@msu.edu), Jan W Brascamp[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

Binocular rivalry is a phenomenon that can be observed when the two eyes receive conflicting information, leading to perceptual alternations between the eyes' images. Evidence suggests, however, that when attention is withdrawn from such dichoptically presented stimuli, these alterations do not continue and the images are, instead, processed equally (Zhang et al., 2011; Brascamp et al., 2011; Eo et al., 2016). This raises the question of how the conflicting images are processed instead. We test the possibility that without attention the conflict is resolved by binocular fusion, so that the conflicting inputs have a combined representation in the cortex (Zhang et al., 2011). We designed an experiment to ensure that two images, when combined during processing, have a measurably different effect than when processed separately, and investigated which effect was obtained when the unattended dichoptic images were presented. Specifically, we made use of the fact that the motion aftereffect (MAE) of two moving gratings, when these are presented superimposed, has a different direction than when they are presented sequentially (Mussap et al., 1998). Our experiment included both such a superimposed condition and such a sequential condition but, critically, also a condition where these two

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gratings were presented to different eyes without attention. We hypothesized, if such dichoptically presented images are fused without attention, this critical condition should yield an MAE direction that matches that of the superimposed gratings. We found that MAE direction in our critical condition, where we presented stimuli dichoptically while withdrawing attention, was significantly different from that in the superimposed condition but similar to that in the sequential condition. We conclude that, without attention, conflicting information from the two eyes is not fused, at least not at the level where our aftereffects arise.

53.350 **Sequence learning causes perceptual suppression of expected stimuli** Elizabeth A Lawler[1], Michael A Silver[1,2]; [1]Vision Science Program, University of California, Berkeley, [2]Helen Wills Neuroscience Institute, University of California, Berkeley

Perception relies on making predictions about the environment, and these predictions are informed by prior experience of regularities. Visual statistical learning allows for rapid acquisition of regularities in visual inputs that can then form the basis of perceptual predictions. We have shown that statistical learning of natural image sequences influences subsequent perceptual selection during binocular rivalry by increasing the likelihood of perceiving an unexpected image over an expected, learned image (Denison et al., 2016). However, creating a predictive context by rotating gratings in a particular direction influences perception in the opposite manner: when presented with a pair of orthogonal gratings in binocular rivalry, observers are more likely to perceive the grating that is consistent with the established direction of motion (Denison et al., 2011). Here, we addressed these conflicting findings regarding the roles of prediction in perceptual selection by examining the effects of stimulus complexity and the method of inducing predictive context. We used statistical learning to teach observers arbitrary sequences of grating orientations and then employed binocular rivalry to measure the effects of statistical learning on perceptual selection. Observers initially viewed sequences of oriented gratings while performing a 2AFC one-back task. Unbeknownst to the subjects, the sequences were composed of concatenated triplets that contained consistent orientations. Following statistical learning, observers performed a rivalry test in which each trial consisted of the first two gratings of a learned triplet presented unambiguously, followed immediately by a rivalrous pair consisting of the third grating from the learned triplet and an orthogonal grating. We found that observers were more likely to initially perceive the unexpected grating that was inconsistent with the learned triplet structure. Our results show that exposure to recently acquired, arbitrary sequential structures impacts subsequent visual perceptual selection and awareness such that the visual system prioritizes the unexpected over the expected.

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53.351 **Auditory cues for gender modulate attention in a binocular rivalry paradigm** Jennifer A Day[1](jeaday@ucsc.edu), Brent Hickey[1], Jeremy Saal[1], Nicolas Davidenko[1]; [1]Psychology department at University of California, Santa Cruz

Binocular rivalry is characterized by the alternating perception experienced when two different images are presented to each eye. There is evidence for both low-level and high-level modulation of binocular rivalry, and while the influence of both systems likely causes the bistable perception an important question remains: how high-level can this modulation occur? Previous studies have used matching and mismatching auditory cues to successfully direct attention to the congruent image. This study examines the influence auditory cues to gender in rivalry between videos of a female or male face reciting the same passage in synch. Ninety participants viewed both videos, one presented to each eye, switching every 20 seconds, while wearing an Oculus Rift headset. There were three within-subject sound conditions; no sound, a female voice, or a male voice. Participants were asked to move a marker along a slider to denote which face (male or female) was more visible along second long-timestamps throughout the course of the video. Although there was a general bias to see the female face across all conditions, we found a reliable gender-consistent interaction: participants were more likely to report seeing the female face when listening to the female voice track than when listening to the male voice track $t(89) = 3.17$, $p = .002$. These results suggest that auditory cues to gender can influence the dynamics of binocular rivalry. We discuss the design of follow-up studies to determine whether these effects stem from high-level associations based on gender representation, low-level audio-visual cues, or both.

53.352 **Vestibular signals modulate perceptual alternations in binocular rivalry from motion conflict** Chris Paffen[1](c.l.e.paffen@uu.nl), Robert Keys[2], Hamish MacDougall[2], David Alais[2], Frans AJ Verstraten[1,2]; [1]Experimental Psychology & Helmholtz Institute, Utrecht University, [2]School of Psychology, the University of Sydney

Visual and vestibular information are both informative about self-motion and recent work shows that vestibular signals can influence visual motion perception. Here we ask whether vestibular input can influence the dynamics of binocular rivalry created by opposed visual motions. In 64 s trials, 10 observers in a CKAS 6 degrees-of-freedom motion platform system (Hexapod) underwent sinusoidal yaw rotations that oscillated between ±15 degrees with a full cycle period of 4 seconds while viewing motion rivalry. Observers viewed left- and rightward moving gratings which were dichoptically presented via an Oculus head-mounted display, and continuously tracked their dominant visual motion percept while their head and eye movements were recorded. The rivalry tracking time-series were epoched into 4 s periods to line up with one cycle of self-motion and averaged to show the mean dominance percept for every position of the yaw-rotation cycle. Fitting a sinewave to the epoched data of each participant showed that rivalry dominance tended to correlate with the direction of yaw rotation. The group mean sine period was 3.88 s, indicating that the motion rivalry dynamics were entrained by the self-motion oscillation. Fitted sine amplitudes varied between observers from 0.04 to 0.31, relative to a maximum amplitude of 0.5. The phase of the sine fitted to the rivalry alternations was stable and tightly linked to the phase of yaw rotation. For 7/10 observers it was in-phase (the dominant motion matched the direction of self-motion), and for 3/10 it was in anti-phase (the dominant motion was opposite to the direction of self-motion). Control data showed that the same yaw rotation had no influence on motion rivalry dynamics between upwards and downwards directions. We conclude that vestibular signals from self-motion input to the visual system and can help resolve perceptual ambiguity from motion rivalry.

53.353 **Binocular Color Grouping of Different Spatial Patterns** Andrew J Coia[1](acoia@uchicago.edu), Emily A Slezak[1, 2], Steven K Shevell[1, 2, 3]; [1]Institute for Mind and Biology, University of Chicago, [2]Department of Psychology, University of Chicago, [3]Department of Ophthalmology & Visual Science, University of Chicago

Separated objects within the visual field that share common features such as orientation, chromaticity, or spatial frequency may be grouped perceptually. For example, the total time when two separated gratings will be seen during binocular rivalry (while rivalling against patches of noise) is longer when they share a common orientation compared to when they are orthogonal (Alais and Blake, 1999, Vis. Research). Sharing multiple features such as color, orientation, and spatial frequency enhances interocular grouping during binocular rivalry (Papathomas, Kovacs, and Conway, 1998, Binocular Rivalry). The current study tests the extent to which binocular grouping by color is diminished if the spatial frequencies of the stimuli being grouped differ. METHODS/STIMULI: Rivalrous chromatic fields were presented dichoptically, with 'red' and 'green' rivalrous gratings swapped between the two eyes at 3.75 Hz. This generated a sustained percept of one color of grating much longer than the alternation rate (after Christiansen, D'Antona and Shevell, 2017, JOV). The rivalruous stimuli were either a full disc, or a grating of either 3.3 or 5.0 cpd within a circular aperture. In different conditions, two rivalrous stimuli at separate retinotopic locations were (i) identical spatially (i.e., two separated discs or two separated identical gratings) or (ii) different (e.g., one disc and one grating, or a 3.3 and 5.0 cpd grating). Also, the orientation of rivalrous gratings could be the same or orthogonal at each retinotopic location. Observers held down buttons when the two separated fields both appeared 'red', 'green' or, in the case of rivalrous orthogonal gratings, plaid. RESULTS/CONCLUSION: Statistically significant grouping of the two separated fields was found for red, green, and plaid percepts regardless of the spatial frequency of the two stimuli (discs, 3.3, or 5.0 cpd gratings). Grouping by color as well as plaid was preserved despite patterns having different spatial features.

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53.354 **Idiosyncratic preferences in motion transparency and binocular rivalry are dissociable**
Byung-Woo Hwang[1](hwang@uni-marburg.de), Alexander C. Schütz[1]; [1]Experimental and Biological Psychology, Philipps-University Marburg, Germany

Previous studies reported idiosyncratic preferences in binocular rivalry during the onset stage (Carter & Cavanagh, 2007; Stanley, Carter, & Forte, 2011). Meanwhile, other studies revealed that there are idiosyncratic preferences to perceive certain motion directions in front during motion transparency depth rivalry (Mamassian & Wallace, 2010; Schütz, 2014). These directional preferences appear to be a fast process that relies on early, 1D motion signals (Schütz & Mamassian, 2016), but it is not clear if they originate at a monocular or binocular processing stage. Here we investigate the relationship of idiosyncratic preferences in motion transparency and binocular rivalry. We presented two overlapping dot clouds that were moving in opposite directions and had opposite contrast polarity (black vs. white). Across trials, the motion direction of the black cloud was varied in 15° steps (24 possible directions). Participants performed two consecutive experimental phases. In the transparent motion phase, both dot clouds were presented to both eyes and participants had to report the color of the dot cloud they perceived in front. In the binocular rivalry phase, the dot clouds were presented to different eyes and participants had to report the color of the dominant dot cloud. We calculated individual preferences for contrast polarity and motion direction separately for each experimental phase. Replicating previous findings, there were strong idiosyncratic directional preferences in transparent motion and rather weak preferences for contrast polarity. The results were reversed in binocular rivalry, showing weak preferences for motion direction but strong preferences for contrast polarity. These findings show that idiosyncratic preferences in a visual feature can be dissociated at different stages of processing. The weak directional preferences in binocular rivalry are in stark contrast to findings from other types of ambiguous stimuli and suggest that the directional preferences in transparent motion arise at a binocular processing stage.

53.355 **BOLD signal modulated with perception in the superficial layer of human V1 during binocular rivalry**
Chencan Qian[1](qianchencan@gmail.com), Chengwen Liu[1,3], Jinyou Zou[1,3], Yan Zhuo[1], Sheng He[1,2], Peng Zhang[1]; [1]State Key Laboratory of Brain and Cognitive Science, Institute of Biophysics, Chinese Academy of Sciences, [2]Department of Psychology, University of Minnesota, [3]University of Chinese Academy of Sciences

During binocular rivalry, the alternation of the two eyes' percept correlates with the fluctuation of neural activities throughout the visual pathway, from as early as LGN and V1 to high-level occipital temporal visual cortices. However, it is not clear how feedforward and feedback processes interact to resolve the rivalrous inputs, and in particular, whether the observed neural fluctuations reflect feedforward, local or feedback modulations of resolved rivalry competition. To answer this question, we used ultra-high field fMRI at 7T with submillimeter resolution to measure rivalry-related signals from different layers of the human primary visual cortex, with the assumption that the middle layer is dominated by feedforward signals while feedback signals modulate the superficial and deep layers. BOLD signals in early visual cortex were acquired with T2*-weighted gradient echo EPI or T2-weighted balanced-SSFP pulse sequences. In the rivalry condition, a pair of orthogonal red and green gratings were dichoptically presented, and subjects reported their percept with button presses (red, green or mixed). In the replay condition, the same red/green gratings were monocularly presented in physical alternations to simulate the rivalry percept. The ocular dominance bias of V1 voxels was determined in separate scans using monocular checkerboard stimulus. Results show that in the replay condition, eye-specific modulation of BOLD signal was strongest in the middle (input) layer of V1; while in the rivalry condition, the rivalrous modulation of BOLD signal was strongest in the superficial layer. A transient signal was also observed, mainly from the superficial layer of V1, at the time points of perceptual transitions in the rivalry but not in the replay condition. These layer-specific fMRI findings support the idea that rivalry-related activity fluctuation in human primary visual cortex reflects feedback modulation from higher cortical areas.

53.356 **Causal Push-and-Pull Modulation of Binocular Rivalry Dynamics using GABAergic Drugs**
Jeff Mentch[1](jsmentch@mit.edu), Alina Spiegel[1,2], Catherine Ricciardi[1], Nancy Kanwisher[1], Caroline E. Robertson[1,3]; [1]McGovern Institute for Brain Research, MIT, Cambridge, MA, [2]Johns Hopkins University, Baltimore, MD, [3]Harvard Society of Fellows, Harvard, Cambridge, MA

Intro: During binocular rivalry, two dichoptically-presented images are suppressed from perceptual awareness in alternation. Computational models of rivalry (Laing and Chow, 2002; Seely et al., 2011; Said and Heeger, 2013) and magnetic resonance spectroscopy research (Robertson et al., 2016) suggest that the depth of perceptual suppression is governed, in part, by the strength of interocular inhibition in visual cortex. Here, we tested a causal link between the strength of perceptual suppression during rivalry and the inhibitory neurotransmitter, GABA, using pharmacological manipulations. Methods: 22 adults participated in each of three separate studies, investigating the effects of a GABAA modulator (Clobazam; study 1), a GABAB modulator (Arbaclofen; study 2), and a Cl- channel modulator (Bumex; study 3) on binocular rivalry dynamics. Each study took place over 3 days: practice session/health assessment (day 1) and two experimental days (day 2-3). On each of the experimental days, a participant was given either a drug or a placebo, and participated in a short binocular rivalry experiment after the drug had taken effect. Results: We found that the GABAA modulator, clobazam, increases perceptual suppression compared with placebo ($p< 0.05$). Conversely, the Cl- channel modulator, bumetanide, reduces perceptual suppression compared with placebo ($p< 0.05$). A repeated-measures ANOVA across studies revealed a significant interaction between these two drugs ($p< 0.001$). Importantly, binocular rivalry dynamics were highly test-retest reliable across testing days (all Rho > 0.65, all $p < 0.001$). Drowsiness ratings did not influence these results. Conclusions: These findings provide a causal, mechanistic link between the GABA pathway and perceptual suppression, as suggested by our previous Magnetic Resonance Spectroscopy research and computational models of rivalry. Further, these results identify specific aspects of the GABAergic pathway which are involved in supporting binocular rivalry. All in all, our results flag perceptual suppression as a marker of GABAergic drug response.

53.357 **Neural representations of orientation and motion direction in human visual cortex during binocular rivalry**
Junshi Lu[1,2,3], Chao Shi[1,2,3], Fang Fang[1,2,3,4]; [1]School of Psychological and Cognitive Sciences, Peking University, [2]Key Laboratory of Machine Perception (Ministry of Education) , Peking University, [3]Beijing Key Laboratory of Behavior and Mental Health, Peking University, [4]Peking-Tsinghua Center for Life Sciences, Peking University

Binocular rivalry occurs when sensory inputs from two eyes are incongruent. Our visual system resolves the ambiguity by preferring one of the stimuli at a particular moment, creating alternating percepts. It is yet unclear how neural representations of low-level visual features are modulated by perceptual alternations in human visual areas. In two experiments, we used fMRI-based encoding models to reconstruct channel responses to suppressed/dominant orientations and motion directions during binocular rivalry. For orientation rivalry, participants first underwent an fMRI session and viewed contrast-reversing sinusoidal gratings of six possible orientations with both eyes. BOLD response patterns were used to train an encoding model of six orientation-selective channels. In binocular orientation rivalry sessions, we presented two orthogonally oriented gratings to the two eyes, and each binocular rivalry run was followed by a replay run to simulate the perceptual effect in the immediately preceding run. Relative to the reconstructed channel responses from the replay runs, we found that, in V1, the channel response to the suppressed orientation was higher during binocular rivalry, while the channel response to the dominant orientation was weaker. These effects were also found in V2 and V3, albeit less pronounced. In V4, the channel response profiles in the rivalry and replay conditions became indistinguishable. For motion direction rivalry, we used RDKs moving in opposite directions with 100% motion coherence as rivalry stimuli. Compared with the reconstructed channel responses from the replay runs, we found elevated responses to the suppressed direction and lowered responses to the dominant direction in V1-V3, V3A, and MT+. Similar to the orientation rivalry experiment, no significant difference was found between

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the rivalry and replay conditions in V4. Taken together, our findings suggest that during the binocular rivalry of low-level visual features, the suppressed information is substantially represented in early and intermediate visual areas.

53.358 **Interocular interaction for second-order stimuli depends on interocular noise correlation and eye dominance** Jian Ding[1](jian.ding@berkeley.edu), Dennis M Levi[1]; [1]School of Optometry, UC Berkeley

Binocular combination of second-order stimuli can be explained by the DSKL model with monocular rectification (Ding & Levi 2017). However, it is unclear whether binocular-combination of second-order stimuli depends on the correlation of the two-eye's first-order carriers. Here, we provide evidence for correlation-dependent interocular interaction. Dynamic bandpass noise was presented to each eye separately using a mirror-stereoscope while a signal, a contrast-modulated (CM) grating (0.68 cpd), was presented to one of the two eyes. The noise had a central-spatial-frequency of 5.44 cpd and was updated every 50 ms with a stimulus duration of 200 ms. In different trials the noise was either correlated, uncorrelated or anti-correlated in the two eyes. The observer's task was to detect the CM grating in the binocularly-combined image by judging its orientation (either left- or right-oblique). The eye with the signal had carrier contrast (CC) of either 0.1 or 0.2, and the other eye (without signal) had CC of 0, 0.25, 0.5, 1, or 2 times of that of the signal eye. Separately, we determined each observer's sighting eye dominance. The results, averaged across four observers with normal binocular vision, show that the CM detection threshold was independent of interocular correlation when the signal was presented to the non-dominant eye. However when the signal was presented to the dominant eye and the other eye's CC was two times the CC of the signal eye, the CM detection threshold was significantly higher ($p < 0.033$ when CC = 0.1; $p < 0.001$ when CC = 0.2) when noise in the two eyes was correlated than when it was uncorrelated or anti-correlated. This phenomenon can be interpreted by a modified DSKL model with an additional term of correlation-dependent NDE-to-DE interaction, e.g., with larger NDE-to-DE suppression or less NDE-to-DE enhancement when the two eyes' images are correlated.

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53.359 **Dis-continuous flash suppression: A novel masking technique reveals temporal integration of subliminal linguistic information** Shao-Min (Sean) Hung[1,2](konaes@gmail.com), Po-Jang (Brown) Hsieh[1]; [1]Neuroscience and Behavioral Disorders Program, Duke-NUS Medical School, [2]Division of Biology and Biological Engineering, California Institute of Technology

It is generally accepted that low-level visual properties such as orientation and color can be processed subliminally to a great extent. However, whether complex information integration can be processed subliminally remains controversial. It is possible that high-order information processing requires stronger subliminal signals that cannot be easily achieved with conventional masking paradigms. For instance, although a thresholding procedure is usually used to obtain the "barely visible" level of signal strength (sub-threshold contrast level), the optimal duration of a subliminal stimulus has rarely been manipulated to achieve optimal signal strength. Here we report a novel form of continuous flash suppression (CFS) that allows longer subliminal presentation: dis-continuous flash suppression (DCFS), in which both the stimulus and the suppressor are presented discontinuously (in a repeated on-and-off manner) to achieve stronger suppression power. In Experiment 1, we found that compared with CFS, given same broken rates, DCFS allowed approximately 50% higher contrast of the stimulus. As for the suppression time, given the same contrast, DCFS allows 50% longer suppression time. In Experiment 2, we further utilized DCFS to examine whether temporal integration of linguistic information occurs while the stimuli were suppressed and remained unconscious. Our results showed that after an invisible 2-word sentence context, the response time of the lexical decision to the following syntactically incongruent word was significantly faster than that to a congruent word. Taken together, we report a novel form of interocular suppression named dis-continuous flash suppression, which allows longer subliminal presentation and may help researchers to lengthen the presentation duration to increase subliminal signals. Furthermore, we show that temporal integration occurs without the stimulus being consciously perceived under DCFS.

53.360 **Low-level properties of dynamic Mondrians, not their predictability, empower continuous flash suppression** Shui'Er Han[1](han.shuier@gmail.com), David Alais[1], Randolph Blake[2,3]; [1]School of Psychology, University of Sydney, NSW 2006, Australia, [2]Department of Brain and Cognitive Sciences, Seoul National University, Daehak-dong, Gwanak-gu, Seoul 151-742, Korea, [3]Department of Psychology, Vanderbilt University, Nashville, TN 37240

In continuous flash suppression (CFS), a rapid, dynamic sequence of Mondrian images presented to one eye can suppress a static target in the other eye for many seconds. Because of its robustness, CFS has become popular for studying unconscious perception, despite limited understanding of its underlying mechanisms. Recent evidence implicates significant contributions from low-level properties (e.g., orientation), but might higher-order influences also impact CFS's potency? For example, the random assortment of shapes in successive Mondrian updates generates pattern information uncertainty that could strengthen suppression exerted on the target. Here we examine the effect of spatial and temporal pattern predictability on CFS potency. Temporally, predictable information entailed updating the Mondrian every 100 ms or sinusoidally modulating pixel luminance at 2 Hz. Irregular update rates and stochastic pixel luminance changes produced temporal uncertainty. Spatially, we reduced predictability by updating the Mondrian with different spatial patterns or we maintained spatial predictability by presenting the same pattern over time, modulating only its luminance contrast. To quantify the effectiveness of these maskers, we had participants track the visibility of a target (contrast modulated concentric grating) over the course of a minute. We also pitted various pairs of discriminable CFS maskers against one another in rivalry. Our results showed that, although the unpredictable spatial masker with fixed 10 Hz change rate dominated the rivalry competition, stronger suppression for spatial uncertainty was only obtained when the target modulated at 4 Hz. We found no effect of spatial and temporal predictability when the target contrast modulated at 0.125 Hz. Since the Mondrian temporal frequency spectrum is characteristically 1/f and hence less compatible with the 4 Hz target, our results suggest that in practice, information unpredictability primarily enhances suppression of a more weakly suppressed target.

Temporal Processing: Neural mechanisms

Tuesday, May 22, 8:30 am - 12:30 pm, Banyan Breezeway

53.362 **The spatial representation of time in visual cortex** Gianfranco Fortunato[1](gianfranco.fortunato@sissa.it), Tatiana Kénel-Pierre[2], Micah Murray[2], Domenica Bueti[1]; [1]International School for Advanced Studies (SISSA), Neuroscience Area, Trieste (Italy), [2]Laboratory for Investigative Neurophysiology (LINE) and Department of Clinical Neurosciences, University Hospital of Lausanne, Lausanne (Switzerland)

Performing a timed movement like dancing, playing a musical instrument or simply walking requires for the brain the integration of both temporal and spatial information. How and where the human brain synergistically links these two types of information remains unclear. Previous studies have shown that primary visual cortex (V1) and extrastriate visual area V5/MT are both involved in the encoding of temporal information of visual stimuli. However these studies do not clarify how time is encoded in these areas and whether V1 and V5/MT encode time differently. Here we tested the hypothesis that V1 and V5/MT encode time in different spatial coordinates, i.e. head-centred versus eye-centred. To this purpose we asked healthy volunteers to perform a temporal discrimination task of visual stimuli that were presented at varying combinations of retinotopic and head-centred spatiotopic positions. While participants were engaged in this task we interfered with the activity of the right dorsal V1 and the right V5/MT by mean of paired-pulse Transcranial Magnetic Stimulation (ppTMS). The results showed that ppTMS over both areas impaired temporal discrimination thresholds of visual stimuli presented at different retinotopic coordinates. V1 TMS affected temporal discrimination of stimuli presented in the lower left visual quadrant whereas V5/

MT TMS the discrimination of stimuli presented in both the upper and the lower left visual quadrants. These results show that both V1 and V5/MT encode visual temporal information in retinotopic spatial frames, but the representation of time is quadrant specific for V1 and hemifield specific for V5/MT.

53.363 **A fronto-parietal network of visual event duration-tuned topographic maps** Ben M Harvey[1](b.m.harvey@uu.nl), Serge O Dumoulin[1,2,3], Alessio Fracasso[2,4,5]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University , [2]Spinoza Center for Neuroimaging, Amsterdam, [3]Experimental and Applied Psychology, VU University Amsterdam, [4]University Medical Center, Utrecht, [5]Institute of Neuroscience, University of Glasgow

Introduction: Precise quantification of sub-second visual event timing is vital to understanding and interacting with our complex, dynamic environment, for example following temporal patterns in sports and traffic. However, despite the central role of timing in perception and action planning, it remains unclear how the brain encodes and represents visual event timing. Converging evidence from psychophysical adaptation, neurophysiology of motor planning and computational modelling suggests the presence of tuned neural responses to specific event durations, together with responses that monotonically increase or decrease with duration. We therefore hypothesized that neural populations in the human brain may exhibit tuned responses to visual event timing, while other brain areas may monotonically change their response amplitude with duration. Methods: We acquired ultra-high field (7T) fMRI data while showing subjects visual events (a circle appearing and disappearing) that gradually varied the time between circle appearance and disappearance (duration) and/or the time between consecutive circle appearances (period, i.e. 1/frequency). We summarized the fMRI responses to these events using neural models tuned to duration and period, following a population receptive field (pRF) modeling approach. Results: Models tuned to event duration captured fMRI responses well in four bilateral frontal and parietal areas. Within these areas, duration preferences progressed gradually across the cortical surface, forming topographic maps of event timing preferences. These timing maps largely overlap with a network of numerosity maps that we recently described. Furthermore, area MT monotonically decreases its responses amplitude with increasing event duration, a likely intermediate stage in computing duration-tuned responses. Conclusion: Neural populations tuned to specific event timings, organized into topographic maps, suggest the neural representation of visual event timing is similar to that of both sensory spaces and other quantities, such as numerosity and object size. Their superior parietal and frontal locations suggest a role in multisensory integration and sensory-motor transformations.

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53.364 **Chronotopic maps in human premotor cortex** Foteini Protopapa[1](fwteini104@gmail.com), Masamichi J Hayashi[2,3], Wietske van der Zwaag[4], Giovanni Battistella[5,6], Micah M Murray[7,8,9], Ryota Kanai[10,11], Domenica Bueti[1]; [1]International School for Advanced Studies (SISSA), Trieste, Italy., [2]Graduate School of Frontier Biosciences, Osaka University, Suita, Japan., [3]School of Psychology, University of Sussex, Brighton, United Kingdom., [4]Spinoza Centre for Neuroimaging, Amsterdam, Netherlands., [5]Icahn School of Medicine at Mount Sinai, New York, USA., [6]Centre hospitalier universitaire vaudois (CHUV) University Hospital of Lausanne, Switzerland. , [7]Vanderbilt University, Department of Hearing and Speech Sciences, Nashville, USA., [8]University of Lausanne, Division of Neuropsychology and Rehabilitation, Lausanne, Switzerland., [9]Jules Gonin Eye Hospital, Opthalmology, Lausanne, Switzerland., [10]Araya, Inc., Tokyo, Japan, [11]Sackler Centre for Consciousness Science, University of Sussex, Brighton, UK.

Time is the most elusive dimension of everyday experiences. We cannot see or touch time nevertheless we clearly sense its flow and adjust our behavior accordingly. The neuronal mechanism underlying our capacity to perceive time remains yet unknown. Single-neuron recordings in animals suggest that the encoding of temporal information in the millisecond/second range is achieved via duration tuning mechanisms. The existence of such mechanisms has never been reported in the human brain. Here, in two independent visual duration-discrimination experiments, using ultra-high-field (7-Tesla) functional magnetic resonance imaging, we found duration-related activations in the medial premotor cortex and the posterior parts of the left parietal lobule of the human brain. More specifically, in the supplementary motor area (SMA), we identified a topographic organization of duration selective voxels i.e., chronotopic maps. Voxels sensitive to the shortest duration were mainly located in the anterior premotor cortex while those responsive to the longest duration in the posterior premotor cortex. This rostro-caudal direction of chronotopic organization was consistent in both experiments. We also showed that the hemodynamic response of each portion of the chronotopic map was enhanced by the preferred and its' neighboring durations and inhibited by non-preferred durations represented in distant portions of the map. These findings identify, for the first time in the human brain, duration-sensitive tuning as a neural mechanism underlying the active recognition of time and demonstrate that the adaptive representation of an abstract feature such as time can be achieved by a topographical arrangement of duration-sensitive neural populations similar to that observed in several cortical and subcortical structures for the processing of sensory and motor signals.

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53.365 **Theta-cyclic binding of visual features** Ryohei Nakayama[1](ryohei.nakayama@gmail.com), Isamu Motoyoshi[1]; [1]Department of Life Sciences, The University of Tokyo

Recent psychophysical studies have demonstrated that attention periodically facilitates visual detection performance at around 5-7 Hz. The present study examined the periodicity of feature binding – another major function of attention (Treisman & Gelade, 1980) – by using a dynamic visual display with conjunctive feature dimensions (Holcombe & Cavanagh, 2001). Observers viewed a pair of stimuli that alternated in/out of phase with each other in brightness (light/dark) and orientation (clock/unclockwise) and reported which of the two attributes appeared more temporally synchronous. The temporal frequency of alternation was manipulated by an adaptive staircase to maintain overall performance at ~70.1%. Correct response rate was obtained across trials for various SOAs with respect to the observer's button press (50-810 msec). We found that the correct rate fluctuated with a periodicity of 6-7 Hz as a function of SOA by means of fitting a sinusoid to individual data. Statistical comparisons with the bootstrapped data and spectrum analyses also confirmed the periodicity. These results support the notion that attention operates periodically not only to facilitate visual processing but also to bind visual features within the theta-rhythm band, and that phase locking in theta-band neural oscillations by voluntary action (Popovych et al., 2016) may underlie the periodicity of visual oscillations.

53.366 **MEG and fMRI dynamics during movie viewing** Kaisu Lankinen[1,2](kaisu.lankinen@gmail.com), Jukka Saari[1], Yevhen Hlushchuk[3,4], Pia Tikka[3], Lauri Parkkonen[1], Riitta Hari[1,5], Miika Koskinen[1,6]; [1]Department of Neuroscience and Biomedical Engineering, School of Science, Aalto University, Finland , [2]Aalto NeuroImaging (AMI Centre and MEG Core), Aalto University, Finland , [3]Department of Film, Television and Scenography, School of Arts, Design and Architecture, Aalto University, Finland , [4]Department of Radiology, Hospital District of Helsinki and Uusimaa (HUS), HUS Medical Imaging Center, Helsinki University Central Hospital (HUCH), University of Helsinki, Helsinki, Finland , [5]Department of Art, School of Arts, Design and Architecture, Aalto University, Finland , [6]Department of Physiology, Faculty of Medicine, University of Helsinki, Finland

Movies, mimicking dynamic visual scenes experienced in our everyday life, provide a useful tool to study brain processes related to natural viewing. Despite the apparent complexity of the movie stimuli, functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG) and electroencephalography (EEG) studies have shown that movies can generate consistent brain activity across viewers. However, little is known about the similarities and differences of hemodynamic and electromagnetic brain dynamics during such natural viewing. We compared MEG and fMRI dynamics in eight subjects who viewed a 15-min black-and-white movie ("At Land" by Maya Deren, 1944) twice during 3-T fMRI and twice during 306-channel MEG recordings. We calculated voxel-wise intra- and intersubject correlations within each imaging modality as well as the correlation between MEG envelopes and fMRI signals. The fMRI signals showed intra- and intersubject correlations up to r = 0.66 and 0.37, respectively, whereas correlations were weaker for the envelopes of band-pass filtered (7 frequency bands within 0.03–100 Hz) MEG signals (intrasubject correlation r < 0.14 and intersubject correlation r < 0.05). Both for fMRI and MEG, the strongest intra- and intersubject correlations took place in occipital areas. Although direct MEG–fMRI voxel-wise correlations were unreliable, MCCA-based spatial-filtering of the MEG data uncovered signal components with intersubject correlations up to r = 0.25. Furthermore, the envelopes of these MEG components below 11 Hz showed statistically significant association with fMRI signals in a general linear model (GLM). Similarities between envelopes of MEG signals and fMRI voxel time-courses were seen mostly in occipital, but also in temporal and frontal brain regions. The results show that the most consistent brain activity across movie viewers occurred in early visual areas, but the association between hemodynamic and electromagnetic activity extended also to higher-order brain areas.

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53.367 **Repetitive Stimulation Enhances V1 Encoding Efficiency** Jacob A Westerberg[1,2,3](jacob.a.westerberg@vanderbilt.edu), Michele A Cox[1,2,3], Kacie Dougherty[1,2,3], Alexander Maier[1,2,3]; [1]Department of Psychology, Vanderbilt University, [2]Center for Cognitive and Integrative Neuroscience, Vanderbilt University, [3]Vanderbilt Vision Research Center, Vanderbilt University

Repeated stimulus presentations reduce responses across many brain areas (repetition suppression) while improving performance in associated tasks (repetition priming). The neuronal mechanisms that allow for enhanced performance in the face of reduced brain activity are unclear. Here we demonstrate that stimulus repetition increases encoding efficiency among cortical neurons, which enhances stimulus representations despite reduced spiking activity. Using a repetition priming-evoking stimulus sequence, we recorded laminar responses in monkey primary visual cortex (V1). We found that repetition suppression is most pronounced outside V1 layers that receive retinogeniculate input and is robust to alternating stimuli between the two eyes, suggesting that repetition suppression is of cortical origin. This V1 spiking suppression is accompanied by sharpened neural tuning as well as increased neuronal synchrony, however not by decreased response latency. These results suggest that repetition priming and repetition suppression arise from modulated cortical neuronal processing that enhances encoding efficiency as stimuli repeat.

Acknowledgement: 1R01EY027402-01, 2T32EY007135-21

53.368 **Larger time dilation induced by 10-Hz flicker is associated with larger 10-Hz neural entrainments** Hiroshi Yoshimatsu[1], Yuki Hashimoto[2], Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo, [2]Graduate School of Interdisciplinary Information Studies, The University of Tokyo

The duration of a flickering stimulus is often overestimated compared with that of a static stimulus. Studies have suggested that neural entrainments induced by the flickering stimulus play a role in this flicker-induced time dilation. However, the way in which neural entrainments modulate the perception of duration remains unclear. To investigate the neural basis of flicker-induced time dilation, we obtained electroencephalography (EEG) measurements during a duration reproduction task. In the experiment, subjects observed a colored target stimulus, which was either flickering at 10 Hz or constantly illuminated. The subjects were asked to observe the target and then reproduce either the duration (duration condition) or color (color condition) of the target. In the reproduction phase, color of the disc gradually changed during the button press. In the duration condition, the subjects reproduced the duration of the target, while in the color condition, the subjects reproduced the color of the target. The results showed that (1) flickering target stimulus induced time dilation, and larger time dilation was associated with larger amplitude of neural entrainments induced by the flickering target. (2) In the reproduction phase, during which only constantly illuminated stimulus was presented, neural activity at around alpha frequency increased when the subjects reproduced the duration of the flickering target. (3) This increase in neural activity at around alpha frequency differed between the duration and color conditions. The results indicate that duration information is coded by oscillatory neural activities, and changing the oscillatory frequencies modulate the perceived duration. The increased power of the flickering frequency during the reproduction phase suggests that the oscillatory activities may be present during memory retrieval.

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53.369 **Cholinergic dysfunction might affect backward masking performance: evidence from schizophrenia** Janir R da Cruz[1,2](janir.ramos@epfl.ch), Maya Roinishvili[3,4], Eka Chkonia[4,5], Patrícia Figueiredo[2], Michael H Herzog[1]; [1]Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Lausanne, Switzerland, [2]Institute for Systems and Robotics – Lisboa and Department of Bioengineering, Instituto Superior Técnico, Universidade de Lisboa, Lisbon, Portugal, [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

In visual backward masking, a briefly presented target is followed by a mask, which decreases performance on the target. We hypothesized that recurrent processing amplifies neural response to the briefly presented target if no mask follows and that this recurrent processing is interrupted when the mask is presented. In this case, neuromodulation, for example of the cholinergic system, may enhance the neural responses to the target. Hence, if neuromodulation is dysfunctional, masking should be strongly deteriorated. Here, we tested schizophrenia patients, a population that is known to have deficits in the cholinergic system, in a masking paradigm while recording their EEG. We found evidence for two mechanisms of neuromodulation: reduced N1 amplitudes and increased trial-by-trial N1 variability. First, N1 amplitudes correlated with performance, and the two were strongly reduced in patients compared to healthy controls. Second, we estimated the N1 variability using a two-step graph-based method and found that patients had higher N1 peak latency variability than controls. After correcting for the latency variability, patients still showed smaller N1 amplitudes than controls. Hence, N1 amplitudes are both diminished and highly variable in patients. Our results suggest that cholinergic system deficits might impair backward masking performance, which is reflected in the EEG N1 component.

Acknowledgement: Swiss National Science Foundation (SNF)

Attention: Neural mechanisms and attentional modulation

Tuesday, May 22, 8:30 am - 12:30 pm, Pavilion

53.401 **Testing the Link Between Feature-Selective Attention and Choice-Probabilities in Primate V2** Katrina R Quinn[1](katrinarosequinn@gmail.com), Stephane Clery[1], Paria Pourriahi[1], Hendrikje Nienborg[1]; [1]Centre for Integrative Neuroscience

During perceptual decisions the activity of task-relevant sensory neurons is typically correlated with an animal's decision. Such decision-related activity, often quantified as "choice-probability", is thought to reflect feed-forward and feedback sources (Nienborg & Cumming, 2009). For a feature-discrimination task, this implies that the feedback is feature-selective. A recent computational account of choice-probabilities (Haefner et al., 2016) hypothesizes that the modulation of sensory neurons by feature-selective attention and the feedback source of choice-probabilities reflect the same mechanism. To test this hypothesis, we leveraged classical findings for feature-selective attention. When an animal attends to a stimulus feature, the responses of neurons selective for this feature are modulated (Treue & Martinez Trujillo, 1999). Critically, this modulation is observed globally, i.e. even when the attended, task-relevant stimulus is in the opposite hemifield to the receptive field of the modulated neuron. Together with the above hypothesis this finding makes a strong prediction: choice-probabilities should be observed globally, including for a task-irrelevant, ignored stimulus. To test this prediction we trained macaques on a disparity-discrimination task on one of two random-dot stereograms, each presented in one hemifield. Only one stimulus, always validly cued, was task-relevant and informative, and the hemifield in which it was presented was switched blockwise. Once the animals successfully ignored the task-irrelevant stimulus, we performed multichannel recordings from disparity-selective units in area V2. In support of the hypothesis, we find substantial choice-probabilities for the ignored stimulus (mean CP=0.59), slightly weaker than and correlated with those for the task-relevant stimulus (mean CP=0.62; r=0.41, p< 10-3, n=71). Importantly, this would not be expected in a feed-forward account, in which choice-probabilities reflect the read-out of the information used by the animal, or in feedback accounts, which differ from feature-selective attention. Instead, these results provide a novel, but predicted, link between feature-selective attention and decision-related activity in sensory neurons.

53.403 **Feature-based attention causes a ring-like modulation of motion direction tuning curves in areas MT and MST of macaques** Sang-Ah Yoo[1, 6](sangahy@yorku.ca), Julio Martinez-Trujillo [2], Stefan Treue[3], John K Tsotsos[4, 6], Mazyar Fallah[1, 5, 6]; [1]Department of Psychology, York University, [2]Department of Physiology and Pharmacology, Western University, [3]Department of Cognitive Neurosciences, German Primate Center, [4]Department of Electrical Engineering and Computer Science, York University, [5]School of Kinesiology and Health Science, York University, [6]Centre for Vision Research, York University

We previously demonstrated that attention to a motion direction inhibits nearby directions using behavioural measures (Yoo et al., VSS 2017), suggesting feature-based surround suppression (Tsotsos, 2011). In the present study, we extended this finding by recording responses of direction selective neurons in area MT and MST of macaques while they viewed different configurations of two random dot kinematograms (RDKs) presented within a RF. One RDK always moved in the neurons preferred direction (preferred pattern); the other could moved in one of 12 different directions (tuning pattern, 30° step). The animals were cued to attend to the preferred (attend-preferred condition) or tuning pattern (attend-tuning condition) and detected a direction change in the attended pattern while ignoring changes in the unattended pattern. In a third condition (fixation), the animals attended to the fixation point and detected colour change while ignoring both patterns. We measured neural responses as a function of the tuning pattern's direction. In all conditions, neurons maximally responded when the tuning pattern moved in the preferred direction. For the attend-tuning and fixation conditions, neuronal responses monotonically decreased as the direction of the tuning pattern became dissimilar from the preferred direction. However, for the attend-preferred condition, the minimal response was observed when the direction of the tuning pattern was 90° away from the preferred direction ($p < .001$), and then the response increased again as the directional difference became greater ($p = .013$). We fitted data from all conditions with three models: Single Gaussian (G), sum of two Gaussians (2G), and Mexican hat (MH). For the attend-preferred condition, the 2G and Mexican Hat functions fitted the data better than the G ($p = .035$). These results demonstrate that feature-based attention produces a modulation of direction tuning curves compatible with a suppressive surround around the attended stimulus feature.

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53.404 **The Impact of Self-Relevance and Valence on Word Processing: an ERP study** Anna Hudson[1](a3hudson@uwaterloo.ca), McLennon J.G. Wilson[1], Emma S. Green[1], Roxane J. Itier[1], Henderson A. Henderson[1]; [1]Psychology, University of Waterloo

Social-cognition implicates a unique processing mechanism for self-relevant information, which has life-long adaptive outcomes. The well-established self-referential encoding task (SRET) specifically probes this self-referential bias, as well as the equally adaptive positivity bias. These two biases have primarily been examined in isolation, separately demonstrating improved endorsement and memory for positive (vs. negative), and self-relevant (vs. other-relevant) trait adjectives. The goal of the current study was to extend this research by simultaneously examining the effect of valence and self-relevance on behavioral indices of memory, and Event Related Potential (ERP) indices of attention and emotion processing at encoding. Using a within-subjects block design, participants viewed and endorsed (or not) positive and negative trait adjectives in terms of themselves (self-relevant block) or Harry Potter (other-relevant block). ERPs were time-locked to word onset and analyses focused on both the early Late Positive Potential (eLPP, 400-600 ms) reflecting sustained attention, and its late counterpart (lLLP, 600-1200ms) reflecting emotional processing. Following the SRET, participants completed unexpected recall and recognition tasks. Consistent with past studies, participants displayed a positivity bias, endorsing and remembering more positive (vs. negative) words. Additionally, participants displayed a self-referential bias, endorsing and remembering more self-relevant (vs. other-relevant) words. The ERP findings paralleled this behaviour, with larger amplitude for self- (vs. other) relevant items from 400-800ms, spanning the eLPP and part of the lLPP. Valence affected only the lLPP with an increased amplitude for positive (vs. negative) trait-adjectives from 600-1000ms. These results suggest the self-referencing and positivity biases might be discrete cognitive processes that do not interact. Self-referential processing seems to start earlier than valence processing, although both overlap around 600-800ms. Additionally, the positivity bias does not appear specific to self-relevant processing, but applies generally across social processing conditions. It appears these two biases have uniquely adaptive roles within social cognition.

Acknowledgement: NSERC Discovery

53.405 **Data-driven region-of-interest selection for visual and attention ERP studies controls Type I error and increases power** Joseph L Brooks[1](j.l.brooks@keele.ac.uk), Alexia Zoumpoulaki[2], Howard Bowman[3,4]; [1]School of Psychology, Keele University, [2]School of Computer Science and Informatics, Cardiff University, [3]School of Psychology, University of Birmingham, [4]School of Computing, University of Kent

Visual phenomena and their neural mechanisms are commonly studied with EEG or MEG measurements (e.g., N170 face-sensitive ERP component; N2pc for visual attention). During data analysis, it is often difficult to know, a priori, precisely where effects will occur on the scalp, in time and in frequency for oscillations work. To overcome this, researchers often identify regions-of-interest (ROIs) for testing, but have been criticized for sometimes using biased, data-driven methods and thereby inflating Type I error rates. Using simulations and analysis of visually evoked N170 and N2pc data, our results demonstrate an ROI-selection method which is data-driven (i.e., based on the collected data), nonetheless, does not inflate Type I error rate. Furthermore, it reduces the need for precise a priori specification of the time and location of the ROI. We identify the ROI using what we call the aggregated-grand average (AGAT) wave, which is a weighted average of trials. We demonstrate that this is orthogonal to the experimental contrast and, importantly, we show that common methods for computing orthogonal waveforms for ROI selection can inflate Type I error rate under some conditions. Based on our results, use of the AGAT overcomes this problem. Finally, we show that using the AGAT has statistical power that can exceed common a priori ROI selection methods by up to 60%. Our results demonstrate a simple, unbiased and data driven ROI selection method which is relevant for N170, N2pc and other visual and attention-related ERP components.

53.406 **Variability in Visuocortical Activation Biases Semantic Decisions** Alexandra Theodorou[1](a.theodorou95@gmail.com), Emily Benny[1], Olivia Krieger [1], Jesse Bengson[1]; [1]Department of Psychology, Sonoma State University

Categorizing incoming visual information from our environment is essential for deciding how to react to situations. Visual search tasks provide evidence that early semantic categorization in the visual cortex occurs soon after the presentation of an image, biasing visual processing in favor of a specific category (Peelen, Fei-Fei & Kastner, 2009). Considering those findings, we incorporated an attentional control paradigm using an arbitrary cue to generate semantic expectancies. Using EEG recording, our results suggest that different magnitudes of activation in the visual cortex soon after the presentation of the arbitrary cue predict decisions to expect a broad semantic category.

Acknowledgement: Sonoma State University Office of Undergraduate Research and Creative Experiences

53.407 **The PR: An ERP index of the reactivation of spatially-specific memories** Hayley EP Lagroix[1](hlagroix@sfu.ca), Taylor Cork[2], Nadja Jankovic[2], Elijah Mudryk[2], Aaron Richardson[2], Kristen Thompson[2], Vincent Di Lollo[2], Thomas Spalek[2]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, Simon Fraser University

When two events occur in close temporal succession, processing of one can affect processing of the other. We discovered a novel electrophysiological component that may elucidate such inter-event interactions. Participants viewed two displays (S1 and S2) shown sequentially in different locations. S1 and S2 each consisted of a target and a distractor presented either on the horizontal or vertical meridian. A pronounced event-related potential positivity, lateralized to the location of the S1 target, was evoked by the onset of S2, which appeared 100-1400 ms after S1. We refer to this component as re-activation positivity (PR). To examine whether the PR indexes disengagement of attention from the S1-target location upon presentation of S2, an irrelevant fixation cross was inserted in the display sequence between S1 and S2. The critical finding was that the PR was elicited by both the fixation cross and by the subsequent S2, providing evidence against an attentional disengagement account. On an alternate hypothesis that the PR represents reactivation of a spatially-specific memory of the S1 target, we examined whether the PR would be modulated by the number of to-be-remembered items in S1. S1 was an 8-item search array containing either one or three digits on the same side of fixation, with all of the other items being irrelevant # symbols. S1 was followed 700 ms later by a task-irrelevant fixation cross and 1400 ms later by S2: a single centrally presented digit. The task was to report whether the S2 digit matched one of the digits presented in the S1 display. The magnitude of the PR elicited by both the fixation cross and S2 was larger when the S1 array contained three digits, compared with one digit. These results suggest that the PR component may index the spatially-specific reactivation of items held in memory.

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53.408 **Comparing the neural dynamics of voluntary feature-based and spatial attention** Mehdi Yazid Senoussi[1](senoussi.m@gmail.com), Niko A. Busch[2], Laurie Galas[3], Laura Dugué[3]; [1]Groupe de recherche en Facteurs Humains et Neuroergonomie, ISAE-Supaéro, Toulouse, France, [2]Institute of Experimental Psychology, Westfälische Wilhelms-Universität, Münster, Germany, [3]Laboratoire Psychologie de la Perception, Université Paris Descartes, Paris, France

Voluntary, covert attention, in the absence of eye movement, selectively enhances visual processing. Attention can be directed to a specific location (spatial-based attention, SBA) or stimulus feature (feature-based attention, FBA). Separate experiments have investigated the neural bases underlying each attention system, but none has compared their temporal dynamics using the same task, stimuli and observers. Here, we used EEG to compare the neural dynamics of both feature-based and spatial-based attentional orienting and reorienting. All participants underwent two experimental sessions: one for each attention condition (FBA/SBA). Each session was composed of a 1h-practice followed by the EEG experiment the next day. During practice, observers were trained to associate iconic stimuli (square/diamond) with two possible instructions: attend to either a specific feature (horizontal/vertical grating) or location (left/right quadrant). In the main experiment, observers performed a 2-AFC orientation discrimination task while recording EEG. Trials started with an iconic cue (120ms) instructing observers to attend to a feature or a location. After a 2s-delay, two gratings were presented for 50ms, one on each side of the fixation cross. A response cue simultaneously appeared to indicate the target grating, and observers were asked to report its orientation (grating tilted clockwise/counterclockwise). A trial was valid when the attended stimulus matched the target (75% of trials) and invalid when it did not match (25%). For both FBA and SBA, d-prime was higher in valid than invalid trials, confirming that iconic cues can successfully manipulate either type of attention. Moreover, we replicated previous results according to which alpha oscillations (~10Hz) lateralize during the preparation interval (between cue and stimuli) in SBA, but not in FBA. Finally, using classification techniques we identified the neural signature of FBA and SBA using the same task, stimuli and observers. This experiment furthers our understanding of the neural bases underlying both attention systems.

53.409 **Neural Markers of Switch-Cost Predict Cognitive Demand Avoidance.** Jeffrey D Nador[1](jeff.nador@wright.edu), Ion Juvina[1], Brad Minnery[2], Assaf Harel[1]; [1]Wright State University, [2]Wright State Research Institute

Generally, people tend to match their cognitive effort to the demands of tasks they encounter. For example, minimizing the costs of switching tasks when given free choice between low- and high-demand variants of the same task. This cognitive demand avoidance (DA) usually manifests overtly in behavior, though it likely also occurs covertly. We sought to assess covert DA by recording Event-Related Potentials (ERPs) in a task-switching go/no-go paradigm. To begin each trial, participants would freely choose between two decks of cards. Upon choosing one, a cue card would appear, its color specifying the task, followed by a target card. Participants were instructed to press spacebar on target appearance if the cue card was red (go), but withhold their response if the target was an ace (no-go); alternatively, if the cue was black, participants were required to press spacebar (go) unless the target was a ten (no-go). Critically, the decks varied in their trial-to-trial probability of task-switching: the low-demand deck switched on 10% of trials, the high-demand deck on 90%. We could thus measure participants' DA as their proportion of low-demand deck selections. To elucidate the covert cognitive decision process underlying DA, we recorded both cue- and target-evoked ERPs. We focused on the P3 component to assess changes related to task switches as a function of DA. Validating our task-switching go/no-go paradigm, we found higher P3 amplitudes for no-go than go trials. Further, we found that P3 amplitude varied as a function of task-switching, with higher amplitude for switch compared to no-switch trials (switch-cost). Critically, this neural marker of task switching was predictive of DA: people with higher P3 switch-cost demonstrated higher DA. We conclude that individual differences in covert DA can be assessed using electrophysiological measures.

Acknowledgement: Office of Naval Research

53.410 **The Role of Bottom-Up Visual Representations in Emotional Decision-Making** Stephen J Phillips[1](phillipsstephen9@gmail.com), Olivia R Krieger[1], Alexandra Theodorou[1], Jesse J Bengson[1]; [1]Department of Psychology, Sonoma State University

While numerous studies have investigated emotion through presentation of visual stimuli, no study has focused on the role of the visual system during decision-driven emotional expectancies. Early visual representations to an otherwise neutral cue may bias decision-making. To test this hypothesis, we measured EEG activity during an attention task in which individuals responded to neutral cues by endogenously generating happy or sad expectancies. Results indicate that early lateralized visuocortical activity predicted subsequent positive and negative decisional outcomes. These results provide evidence that decision-making, even for abstract emotional categories, is influenced by early visual responses to neutral stimuli.

Acknowledgement: Sonoma State University Office of Undergraduate Research and Creative Experiences

53.411 **Alpha power, working memory (WM) and Attention Deficit Hyperactivity Disorder (ADHD) symptoms among children with ADHD** Shira Frances-Israeli[1](shirafrn@gmail.com), Inbar L Trinczer[1,2], Shlomit Greenberg-Yuval[2,3], Roy Amit[2], Noa Rotman[1], Lilach Shalev[1,2]; [1]School of Education, Tel Aviv University, [2]Sagol School of Neuroscience ,Tel Aviv University, [3]School of Psychological Sciences, Tel Aviv University

ADHD is a childhood disorder characterized by inappropriate levels of inattention and/or hyperactivity/impulsivity, resulting in impairment in multiple life domains. One of the deficient cognitive mechanisms in ADHD is WM, though different studies have found varying results in regard to the role of WM in ADHD. Previous EEG studies showed inconsistent findings regarding anomalous alpha activity in participants with ADHD. For instance, some found asymmetric rightward alpha in children with ADHD compare to control, while others did not find these differences. The aim of this study was to examine the relations between resting state EEG alpha power, WM performance and ADHD symptoms among ADHD children. The sample was comprised of 28 children (aged 8-12 year-olds) diagnosed with ADHD according to DSM-IV criteria. All participants completed a battery of cognitive tasks and a 5 minutes session of eyes-closed resting state EEG recording. Consistently with previous findings, a significant negative correlation was found between the magnitude of Hyperactivity/Impulsivity symptoms and the performance in a backward visuospatial WM task, indicating that severe symptoms of hyperactivity and impulsivity were correlated with lower WM performance. In addition, central alpha asymmetry and performance in a backward phonological WM task were highly correlated. That is, the more rightward the central alpha was the worse the WM performance. Further studies are necessary to investigate these relations and their potential contribution in early identification of young children who are at risk for developing difficulties in working memory and later on in academic performance. The search for early identification may enable us to support children by introducing early individually tailored intervention programs in order to improve their WM performance, and in turn, facilitate learning in various contexts.

53.412 **The role of pre-stimulus alpha oscillation in distractor filtering during a Visual Search task** Aleksandra Pastuszak[1](a.pastuszak@pgr.bham.ac.uk), Kimron L Shapiro[1], Simon Hanslmayr[1]; [1]School of Psychology, College of Life and Environmental Sciences, University of Birmingham

It is widely accepted that high occipital alpha power is detrimental to performance on visual perception tasks(Ergenoglu, et al.,2004). However, given the evidence of occipital alpha oscillations playing a role in inhibition of distracting stimuli(Worden, 2000; Foxe, et al., 1998), we hypothesize that pre-stimulus alpha power acts as a filter for interfering stimuli, which can be optimised based on the expected amount of distracting information. We investigated this relationship between pre-stimulus alpha power and attention using a conjunction Visual Search(VS) task(Triesman, et al. 1980). Based on previous research and pilot data we anticipated a negative correlation between pre-stimulus alpha power and reaction times(RTs), with high alpha power being related to improved performance, reflecting the inhibition of distractors. We also expected that anticipation of the difficulty of oncoming trials, would result in modulation of pre-stimulus alpha power, with high set size conditions showing higher alpha power as compared to low set size conditions. Thus, we conducted two VS studies using electroencephalography. In Experiment 1 set size conditions were randomly intermixed throughout the experiment, and thus the oncoming trial difficulty was not predictable. In Experiment 2 we employed a blocked design, preceding each block with information of the set size so that trial difficulty could be anticipated. In both experiments we find a significant negative correlation between pre-stimulus occipital alpha power and RTs, in the high set size condition, with high alpha power being related to faster RTs and vice versa. We show, that when it is possible to anticipate task difficulty, pre-stimulus alpha power is modulated in preparation, with high set size conditions showing significantly higher pre-stimulus alpha power as compared to low set size conditions. These results indicate that occipital alpha is indeed a filtering mechanism which can be optimised depending on the amount of anticipated distracting information.

53.413 **Age-mediated parietal contribution to salience suppresion** Carmel Mevorach[1,2](c.mevorach@bham.ac.uk), Brandon K Ashinoff[1], Stephen D Mayhew[1,2]; [1]School of Psychology, The University of Birmingham, UK, [2]Centre for Human Brain Health, The University of Birmingham, UK

Cognitive aging has been associated with a decline in inhibitory processes. Older participants seem to be less capable at inhibiting distractors, especially when they are more salient than targets. While various neuronal changes have also been documented as a function of age the underlying brain mechanisms that mediate this behavioural change are still poorly understood. Interestingly, there is a striking similarity between old participants' performance in a salience-suppression task (Tsvetanov et al., 2013) and the effect of inhibitory brain stimulation over the left IPS in young participants performing the same task (Mevorach et al., 2009). Furthermore, the left IPS contribution in young participants appears to be proactive - in anticipation of the impending stimuli. Proactive control is thought to be specifically impaired in old age, where a shift toward reactive control (a late-correction mechanism) has been observed (Braver, 2012). To assess whether brain activation patterns in old age fit with this idea of shift from proactive to reactive control, we recorded brain activation using fMRI in two groups of old and young adult participants while they performed a salience-based suppression task. Specifically we ask whether activations in left IPS or left TPJ (previously linked to reactive control in young adults) are mediated by age. Our results show a qualitative difference in brain activation in the two groups when salient distractors had to be ignored (which is apparent even when global differences in cerebral blood flow between the groups are controlled for). While both groups show left IPS activation, the older participants seem to rely on additional activation in the left TPJ (as well as left IFG). We argue that this left lateralized parietal activation is associated with a reactive inhibition network that is most likely engaged in old age to overcome an initial capture by the salient distractors.

53.414 **Frontoparietal cortex encodes task set only when it is needed** Shinyoung Jung[1](mental.zero@outlook.com), Suk Won Han*[1]; [1]Department of Psychology, Chungnam National University

The present study investigated how the frontoparietal network of the human brain is engaged when a task set is formulated, maintained, and executed. In an fMRI experiment, participants performed a cued-switching task. The target stimulus was created by superimposing an image of a face and an image of a building. At the beginning of each trial, a cue, indicating whether the face or the building should be attended, was presented. In the face task trials, participants performed the gender identification task (male/female), while in the building task trials, the building structure discrimination (1 story/ 2 story) was performed. The cue and target presentations were separated by jittered intervals (4, 8, or 12 secs). Importantly, we intended to include long intervals (8 or 12 secs) to separately examine cue- and target-evoked activities. As results, the frontoparietal regions (lateral prefrontal cortex and intraparietal sulcus) showed transient responses at the onsets of the cue and target. Notably, we found no evidence that the cue evokes sustained activation, preparing for the target presentation. Subsequent multivariate pattern analysis (MVPA) revealed that the two tasks elicited differential activation patterns from the frontoparietal regions. However, the task sets were able to be decoded only from target-evoked activation, p's $< .05$. The cue-evoked activity did not encode any task information. These findings challenge the predominant account that task cues evoke sustained activation, encoding task representations. Instead, we suggest that the coding of task sets in the frontoparietal regions becomes apparent at the moment when the task rule should be applied (target onset). This supports the adaptive coding model of the human brain, suggesting that the frontoparietal regions' task coding is determined by task demands (Woolgar, Hampshire, Thompson, & Duncan, 2011).

53.415 **Dissociating proactive from reactive control in multiple-target visual search** Eduard Ort[1](e.ort@vu.nl), Johannes J. Fahrenfort[1], Michael Hanke[2,3], Falko Kaule[2,4], Reshanne Reeder[4], Stefan Pollmann[3,4], Christian N. L. Olivers[1]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, [2]Psychoinformatics Lab, Otto-von-Guericke University Magdeburg, Germany , [3]Center for Behavioral Brain Sciences, Otto-von-Guericke University Magdeburg, Germany, [4]Department of Experimental Psychology, Otto-von-Guericke University Magdeburg, Germany

Cognitive control can involve proactive and reactive mechanisms. Little is known about pro- and reactive control in visual search, when observers look for pre-defined targets among distractors. Using a gaze-contingent eye-tracking paradigm, we recently provided evidence consistent with different modes of control in multiple-target search. We instructed participants to simultaneously search for two possible target objects presented among distractors, and select one of them. In one condition, only one of the two targets was available in each display, so that the choice was imposed, and a reactive control mechanism would be required. In the other condition, both targets were present in a search display, which gave observers free choice over what to search for, and allowed

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for proactive control. Switch costs emerged when targets were imposed, while no switch costs emerged when target selection was free. Using a unique combination of fMRI with the same fast-paced gaze-contingent eye-tracking paradigm, we examined which cortical regions were selectively activated by proactive and reactive control mechanisms during multiple-target search. Based on earlier findings, we expected regions in the lateral prefrontal cortex to be active during both types of control. Results indeed support the involvement of the fronto-parietal attention network, including SMA/pre-SMA, anterior cingulate cortex, intraparietal sulcus, precuneus, and anterior insula, both when choice was imposed and when it was free. Moreover, we found activations in the frontopolar cortex specific for the free choice conditions, which supports the recent idea that the frontopolar cortex is involved in evaluating alternative goals. Finally, we present the results of a deconvolution analysis to uncover any differences in the time course of activations associated with different modes of control.

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53.416 **Change Blindness: Is V1 change blind ?** Akhil Edadan[1,2](a.edadan@uu.nl), Wietske Zuiderbaan[2], Alessio Fracasso[2,3], Serge O Dumoulin[1,2,4]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University, Netherlands, [2]Spinoza Centre for Neuroimaging, Amsterdam, Netherlands, [3]Radiology, University Medical Center Utrecht, Netherlands, [4]Experimental and Applied Psychology, VU University Amsterdam, Netherlands

Our internal representation of the visual world is not as detailed as we perceive it to be, as illustrated by the change blindness paradigm wherein people fail to detect large changes in a visual scene. Here we investigate at what level of visual processing this information is lost. Since it is well established that primary visual cortex (V1) is strongly modulated by contrast energy, we ask whether we can identify high contrast changes from V1 even if they are not detected by the subjects. We acquired fMRI data while participants viewed pairs of images (natural and synthetic) shown consecutively. The image pairs were either the same image or different images with a contrast change introduced in the second image. This gives us three conditions, both images at high contrast, both images at low contrast and alternating high and low contrast (change). To visualize the results we projected the fMRI activity of each recording site into visual space using their corresponding pRF (population receptive field) for each condition. We also predicted the visual space representation from the images based on the RMS contrast. We showed that the visual space representations are very similar between fMRI control conditions and RMS predictions. Next, we reconstructed the visual space representations evoked by the change condition as compared to control conditions. For the synthetic images, results from 4 subjects show that V1 visual space projections differ in the changed region for change condition as compared to the control conditions. In the natural images, we were able to identify the changes from the V1 visual space projections in some but not all images. We speculate that the nature of the change may influence our ability to detect the changes. To conclude, V1 can detect changes in a scene without reaching conscious awareness.

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53.417 **How Top-down Attention Alters Bottom-up preconscious operations** Peter U Tse[1](peter.tse@dartmouth.edu), Peter J Kohler[2], Eric A Reavis[3], LiWei Sun[1], Kevin Hartstein[1], Gideon Caplovitz[4]; [1]Psych Brain Sciences, Dartmouth College, [2]Psych Dept.,Stanford University, [3]Medical School, UCLA, [4]Psych Dept., U Nevada at Reno

While the selective and facilitatory roles of attention have been extensively characterized, there is an ongoing debate about whether attention can alter subjective visual experiences. Here we demonstrate that attention can strongly modulate subjective visual experiences in areas as diverse as perceived color, brightness, size, shape, and direction of motion, as well perceived sound, in certain case where the stimulus is multiply interpretable. We hypothesize that attention can specify a domain or framework, such as a boundary or layer, within which constancy and other constructive processes subsequently operate. The outputs of these preconscious processes within the attended domain are then experienced consciously. Here we demonstrate that human observers can deploy attention to selectively demarcate specific surface, layer and figural boundaries and thereby affect which constructive processes will operate and how they will operate. Top-down volitional operations can therefore constrain what the outputs of bottom-up operations will be. In order for this to be possible, attention must be able to reach down into the preconscious buffer in order to define a domain. Our data (Sun et al., 2017) suggest that this buffer spans ~300ms of processing, and that top-down volition can reach down into this buffer and alter its perceptual outputs. How such top-down ‘reaching down’ might operate at a neural circuit level will be considered. In particular, the ‘binding-by-bursting’ theory of Tse (2013) in which attention sets up a ‘bucket brigade’ of information processing from the LGN to V1 down the ventral stream to the hippocampus for identification will be modified to take into account the idea of domains of preconscious operator operations.

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53.418 **Continuous theta burst TMS of area MT impairs attentive motion tracking** Tiffany T Tran[1](tt24tran@edu.uwaterloo.ca), Arijit Chakraborty[1], Deborah Giaschi[2], Benjamin Thompson[1]; [1]School of Optometry and Vision Science, University of Waterloo, [2]Department of Ophthamology, University of British Columbia

Multiple object tracking (MOT) is impaired in amblyopia. This deficit has been associated with reduced MT activity during MOT task performance, suggesting that MT plays an important role in attentive tracking. To test this possibility, we assessed whether modulation of MT activity using inhibitory continuous theta burst stimulation (cTBS) would influence MOT performance in participants with normal vision. The MOT stimulus consisted of 4 targets and 4 distractors and was presented at 10° eccentricity (right and left hemifields). Functional MRI-guided cTBS was applied to left MT at 100% of active motor threshold intensity. Participants (n=15, age: 27±3) attended separate active and sham cTBS sessions. During cTBS, the MOT task was presented at each participant’s speed threshold. Percent correct (based on partial report) for 40 trials was measured at baseline (before cTBS) and 5min and 30min after cTBS stimulation. Baseline accuracy did not vary between the right and left hemifields. There was a significant interaction between cTBS type (active/sham) and measurement time (baseline/post cTBS 5min or 30min) ($F_{2,18}$=5.71, p=0.01). For active cTBS, there was a significant reduction in accuracy from baseline for the right hemifield after 5min (10 ± 2% reduction; t14 = 1.95, p = 0.03) and after 30min (15±3% reduction; t14=2.96, p=0.01). The left hemifield exhibited improved accuracy 30min after active cTBS (6±1.5% improvement, t14=-2.24, p=0.02). For sham cTBS, accuracy improved in both hemifields equally (right: 9 ± 2% improvement; t14=-2.94, p=0.02 and left: 9±1.5% improvement; t14=1.95, p=0.04). Our results demonstrate that cTBS of MT impaired MOT accuracy. There were improvements in MOT accuracy in the control hemifield and in the sham condition suggesting a task learning effect. These results highlight the importance of lower-level motion processing for MOT and support previous findings indicating that impaired MT function is responsible for MOT deficits in patients with amblyopia.

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53.419 **Long-Term Functional Connectivity Changes Across The Dorsal Attention Network After Transcranial Electrical Stimulation** Federica Contò[1,2](federica.conto@unitn.it), Grace Edwards[1, 3], Lorella Battelli[1,4]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, Via Bettini 31, Rovereto, 38068, Italy, [2]Center for Mind/Brain Sciences, University of Trento, Via Bettini 31, Rovereto, 38068, Italy, [3]Harvard University, Cambridge (MA), USA , [4]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts, USA, 02215

Introduction: High-frequency tRNS (hf-tRNS) has been shown to modulate ongoing cortical oscillations and facilitate behavior in a number of cognitive tasks, including sustained attention (Tyler et al., in press). These studies mainly analyze the neuromodulatory effects by measuring changes in performance. However, the impact of hf-tRNS on large-scale cortical networks is still unknown. In this study we investigated the impact of multi-session hf-tRNS coupled with behavioral training on resting-state fMRI before and after training. Methods: Thirty-three subjects participated in a 6-days experiment. Subjects received 25min

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hf-tRNS or sham while training on an interleaved visual and temporal attention task for 4 consecutive days (day 2-5). Subjects were assigned to one of three conditions in a between-subject design: 1) hf-tRNS over parietal cortex, 2) over hMT+, and 3) sham stimulation. Before and after the training phase (day 1 and 6), we measured rs-fMRI of selected nodes of the Dorsal Attention Network (DAN). To detect changes in functional connectivity, correlation matrices containing all DAN nodes were calculated and compared before and after hf-tRNS and between stimulation conditions. We expected concurrent hf-tRNS to affect large-scale functionally selective attention network. Results: Resting state functional connectivity patterns significantly increased within the main nodes of the DAN (in particular hMT+, IPS and FEF) after parietal stimulation. No significant changes were found for the hMT+, nor sham group. Crucially, behavioral performance significantly improved for subjects in the parietal group only. Conclusions: tRNS has a sustained and selective effect upon functional networks involved in attentional training. Changes in resting state functional connectivity within the DAN demonstrate how noninvasive cortical modulation can boost behavior after very short training. This work highlights the importance of a network perspective to understand the impact of brain stimulation on the brain.

Binocular Vision: Stereopsis

Tuesday, May 22, 8:30 am - 12:30 pm, Pavilion

53.420 **Perceptual adaptation to disparity is not well explained by responses in V1** Paul L Aparicio[1](paul.aparicio@nih.gov), Bruce G. Cumming[1]; [1]Labratory of Sensorimotor Research, National Institutes of Health

Adaptation is ubiquitous in the visual system, but how perceptual adaptation relates to neural adaptation is unclear. Studies with orientation suggest that a fixed readout of adapted neurons in V1 can explain perceptual adaptation, but this has been difficult to test directly. Here we examine whether a fixed read out of V1 can explain the perceptual shifts produced by adaptation to disparity in random dot patterns. We exploit the systematic relationship between the effects of correlated and anticorrelated adaptors to provide a direct test. Adaptation was measured with 3s stimuli where the first half consisted of the same adapting disparity (correlated or anticorrelated), and the second half contained a random mixture of correlated disparities. This produced systematic changes in spike count during the second half of each trial. In units of dprime, correlated adaptors produced a change ~3.5 times larger than anticorrelated adaptors at the same disparity (n = 126 neurons from two monkeys). A similar trial structure was used in separate experiments to assess the perceptual effect of adaptation in the same two monkeys. Separate 1.5 sec adaptor and test trials alternated, and choices were only reported after test trials. Test trials that had no signal (20%), were identical to the second 1.5sec used for neural recording. While psychometric curves were shifted further by correlated than anticorrelated adaptors, the relative magnitude of the perceptual shift (anticorrelated adaptor/correlated adaptor) was much greater than the relative magnitude observed for neurons. The ratio of the behavioral difference to the neural difference was 2.4 ($p< 0.052$) and 9.4 ($p< 0.002$) for each monkey, a six-fold difference on average. The observed relative effect size is hard to reconcile with a fixed readout of V1 neurons, suggesting that the perceptual effects of adaptation require adaptor-induced changes in processing beyond the primary visual cortex.

53.421 **The effect of edge separation and orientation on the perception of depth in anti-correlated random dot stereograms** Jordi M Asher[1](jashera@essex.ac.uk), Paul B Hibbard[1]; [1]University of Essex, Department of Psychology

The perception of depth depends on the calculation of a binocular cross-correlation by cortical neurons. The binocular energy model of neural responses predicts depth might be perceived in the reversed direction when the contrast of dots presented to one eye is reversed. Presenting an anti-correlated random-dot stereogram target (aRDS) adjacent to a correlated random-dot stereogram background (cRDS) has produced reversed depth, however these results are inconsistent (Hibbard et al., 2014). Aoki et al., (2017) found robust perception of reversed depth when there was a non-zero absolute disparity for the surrounding cRDS, and a zero disparity aRDS. They suggest that the mixed findings across studies may be accounted for by the presence of a spatial gap between the target and surround. Alternatively, the perception of reversed depth may be a result of the overlap of background and foreground features around the vertical edges of the stimuli, rather than the absence of a gap. To test this, we assessed whether (1) the gap size (0, 10 or 20 arc min) (2) the correlation of dots (aRDS or cRDS) or (3) the border orientation (circular target, or horizontal or vertical edge) affected the perception of depth. For a minority of observers, reversed depth was seen in aRDS for the circular target when no gap was present, and this effect reduced as the gap size increased. However, when scores were averaged across observers, performance on aRDS stimuli was at chance. Depth was mostly perceived in the correct direction for aRDS edge stimuli, with the effect increasing with the gap size. The inconsistency across conditions suggest a complex interaction between first- and second-order depth detection mechanisms and the range of spatial frequency tuning. The separation between target and surround does not appear to exclusively account for the perception of reversed depth in aRDS stimuli.

53.422 **The spatial frequency effect on perceived depth from disparity** Pei-Yin Chen[1](d02227102@ntu.edu.tw), Chien-Chung Chen[1,2]; [1]Department of Psychology, National Taiwan University, Taipei, Taiwan, [2]Center for Neurobiology and Cognitive Science, National Taiwan University, Taipei, Taiwan

The disparity energy model suggested that disparity is coded by neurons whose receptive fields for the left and right eye inputs have similar spatial frequency (SF) selectivity but with a p/2 phase-shift. The phase shift between the two RFs determines the preferred disparity of the channel. Thus, the disparity selectivity of a channel depends on its preferred SF (Fleet et al., 1996; Ohzawa et al., 1990; Sanger, 1988). Here, we investigate whether the SF of band-pass noise stereograms affect the perceived depth from disparity. The test stimuli were rectangular band-pass noise stereograms (1.27 x 3.44 degree), in which the binocular disparity at each location was determined by a raised cosine function (0.29 cycle/deg) to give a bulge or depression percept. The band-pass filter is a Gaussian distribution centered at 1.5, 3 or 5 cycle/deg with a bandwidth of one octave. The maximum test disparity ranged from 0 to 24 arc min while the luminance contrast ranged from 5% to 80%. The observers' task was to adjust the length of a horizontal bar to match the perceived depth in the test stimuli. Regardless the central SF of the band-pass filter, the perceived depth was an inverted-U disparity matching function. Furthermore, for each SF condition, both peak and peak position of the disparity matching function increased with luminance contrast. As the peak SF increased, the peak of the disparity matching function increased while the peak-position decreased. Thus, the perceived depth depends on both luminance contrast and SF of the test pattern. Our results cannot be explained by a phase-encoding disparity energy model, which would predict that the perceived depth to be a constant within each SF band. Instead, our result suggests a disparity averaging across channels that subject to contrast gain control, which can be affected by SF filtering.

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53.423 **Adaptive spatial re-weighting in stereoscopic depth perception revealed by disparity reverse correlation** Takahiro Doi[1](doi.takah@gmail.com), Johannes Burge[1,2,3]; [1]Department of Psychology, University of Pennsylvania, [2]Neuroscience Graduate Group, University of Pennsylvania, [3]Bioengineering Graduate Group, University of Pennsylvania

The spatial structure of binocular disparity depends on the natural scene that an observer is viewing. For example, disparities are spatially uniform (at least locally) when observers are facing a wall, but disparities are spatially variable when observers are viewing the foliage of a bush. Stereoscopic depth estimates benefit from adaptive spatial pooling: large pooling regions should be used with uniform disparity patterns and small pooling regions should be used with more variable disparity patterns. To test if the humans use adaptive pooling, we conducted a reverse correlation experiment in the disparity domain. The task was to report if the central region of a random-dot stimulus appeared nearer or farther than the zero-disparity surround. The center region consisted of nine horizontal bars (60×6 arcmin) vertically flanking the fovea. Each bar's position in depth was determined by a signal disparity (+0.34 or –0.34 arcmin depending on the trial) plus independent Gaussian disparity noise. In the first condition, disparity noise variance was spatially uniform (1.71 arcmin2). In the second condition, noise variance increased with eccentricity mimicking how disparity variance increases with eccentricity in natural viewing. The total noise variance was the same between the two conditions. In the first condition, the ideal observer uniformly weights disparities at all eccentricities. In the second condition, the ideal observer gives larger weights to more foveal disparities (reliability-based weighting). We ran ~5,000 trials per condition to estimate the weights. Results demonstrate that the ideal observer predicts the observed pattern of adaptive spatial reweighting. When disparity noise increases with eccentricity, the spatial weight sharply decreased with eccentricity. When the noise variance was uniform across space, the weights were more nearly constant. We conclude that the spatial window underlying stereoscopic depth perception is adaptively regulated based on the spatial noise structure.

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53.424 **Why is horizontal disparity important for stereo depth?** Bart Farell[1](bfarell@syr.edu), Cherlyn J. Ng[1]; [1]Institute for Sensory Research, Dept. of Biomedical and Chemical Engineering, Syracuse University

Horizontal disparity plays an important role in theories of stereopsis and in the creation of stereoscopic scenery. The conventional explanation for its effectiveness is the nominally horizontal separation of the eyes, which makes horizontal the dominant disparity direction. Without denying this reason, an unconventional response might point to two qualifications: (1) Horizontal disparities do not play a special role in the perception of the stereo depth of one-dimensional stimuli. (2) The two-dimensional laboratory stimuli from which we know so much about stereo vision have almost exclusively been vertically oriented, symmetric about the vertical, or isotropic. The average effective disparity direction of these stimuli—measured perpendicular to component orientations and down-weighting horizontally oriented components—is horizontal. We tested perceived-depth predictions from horizontal disparities against those from averaged perpendicular disparities. We used oriented two-dimensional stimuli: plaids whose sinusoidal components had a 30 degree orientation difference. The plaid's orientation, given by the mean of the component orientations, was either vertical or oblique. Two plaids appeared on each trial for 176 ms. Their orientations were the same or different, as were their retinal disparity directions, which were perpendicular to the plaid's orientation or at an angle from the perpendicular. The disparity magnitude of one stimulus varied across trials; the other disparity was constant. Observers judged the relative depth of the two stimuli, without feedback. Perceived depth, measured by the point of subjective depth equality, followed the orientation-specific disparity predictions rather than horizontal disparity predictions: Perceived depth varied with relative disparity in the direction perpendicular of the average stimulus orientation. We suggest that depth from disparity is calculated along this perpendicular direction, and therefore the effective disparity direction varies with the orientation of the stimulus rather than being imposed by the horizontal separation of the eyes.

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53.425 **Behavioural sensitivities to disparity-defined faces** Idy Wing-yi Chou[1](idychou@connect.hku.hk), Dorita H.F Chang[1]; [1]Department of Psychology, The University of Hong Kong, Hong Kong

We tested the perception of disparity-defined depth under naturalistic and unnaturalistic contexts. Stimuli consisted of random-dot stereograms depicting upright faces, inverted faces, or curvature-matched surfaces. Observers completed two tasks in which they were asked to judge whether the target was in front or behind of a surround (SNR task) or which of two consecutively presented targets was nearer (feature task). Stimulus difficulty was manipulated by adjusting the percentage of dots laying on versus off the target's surface (SNR task), or adjusting the disparity difference between the two consecutively presented targets (feature task), via a staircase (QUEST) procedure. For the feature-discrimination task, thresholds were lower (better) for the curvature-matched control surface, than for the face stimuli at either orientation. Thresholds for the SNR task, however, did not differ across the three conditions. Our data suggest that object context can significantly influence disparity judgments, potentially as a consequence of feedback from traditional extrastriate object-related regions.

53.426 **Human binocular disparity estimation with natural stereo-images** David N White[1](davey@autistici.org), Johannes Burge[1,2]; [1]Neuroscience Graduate Group, Biomedical Graduate Studies, University of Pennsylvania, [2]Department of Psychology, University of Pennsylvania

Binocular disparity is a primary cue for depth perception. How well do humans estimate binocular disparity under natural conditions? What sources of uncertainty limit performance? What is the relative importance of each source? To answer these questions, we first sampled thousands of stereo-image patches from a recently collected stereo-database of natural scenes. Then, we used these stimuli to measure disparity discrimination performance in three human observers in a 2IFC experiment (1deg, 250ms). Each interval of every trial contained a unique contrast-fixed natural stimulus; no stimulus was presented twice. The task was to select the interval with the stimulus that was stereoscopically further away. For each of five standard disparities across an ecologically valid range (-11.25 to -3.75arcmin), we measured a nine-level psychometric function (100trl/lvl). Then, we fit each function with a cumulative Gaussian, and computed the discrimination threshold (d-prime = 1.0). Consistent with classic results, discrimination thresholds increased exponentially with disparity for each observer, confirming that the exponential law of disparity discrimination holds with natural signals. Next, each human observer repeated the experiment with the same stimuli on each trial but in a random order. This double-pass design allowed us to estimate the correlation in the observers' decision variables across the two passes of the experiment. Decision variable correlation must be stimulus-driven, because the stimuli contained the only source of uncertainty that was correlated across both passes. From the correlation we determined the ratio of uncertainty contributed by natural stimulus variability and decision noise. This ratio was approximately 1.0 for all conditions, indicating that natural stimulus variability limits performance at least as much as internal noise. Thus, natural signals have a consistent, important, and quantifiable impact on human disparity discrimination performance. Future work will model and predict the impact of natural stimulus variability on human performance this task.

53.427 **The effects of object plausibility on disparity perception** Nicole Wong[1](nicole26@connect.hku.hk), Dorita H.F. Chang[1]; [1]Department of Psychology, The University of Hong Kong, Hong Kong

Binocular disparity is one of the most important cues for retrieving depth from object structures. However, little is known as to the mechanisms underlying disparity-based depth processing under complex contexts. In two experiments, we asked how the plausibility of complex 3D objects, as dictated by the conformity of the stimulus with natural physical laws, affects the retrieval of disparity information. Stimuli were disparity-defined 3D objects (triangle and cube) rendered as random dot stereograms (RDS). Stimuli were presented in possible and impossible variations (e.g., a normal versus a Penrose triangle). Observers were asked to complete both a signal-noise task, judging whether the object was in front or behind of a reference plane, and a feature discrimination task, judging which of two consecutively presented targets was nearer. Task difficulty was manipulated via the QUEST staircase procedure. We varied the percentage of signal dots laying on versus off of the object surface (SNR task), or the disparity difference (1-150 arcsecs) between the objects presented in the two intervals (feature task). Interestingly, results showed greater sensitivities of SNR-based depth judgments for impossible versus possible objects. We observed a subtler advantage for judging depth of impossible objects in the feature task. Our data suggest that disparity representations may be modulated by higher order contextual information, signalling an intrinsic relationship between object and disparity processing.

53.428 **Vergence adaptation in hyperopic children with and without a strabismic history** Yifei Wu[1](wuyif@indiana.edu), Sonisha Neupane[1], Vidhyapriya Sreenivasan[1], Don W. Lyon[1], Katie S. Connolly[1], T. Rowan Candy[1]; [1]School of Optometry, Indiana University Bloomington

Introduction: Approximately 20% of children with hyperopia greater than +3.5D develop accommodative esotropia. How do strabismic children differ from the 80% with aligned eyes? Infants and young children experience changing accommodation and vergence demands due to emmetropization and head growth. Typically developing young children and pre-presbyopic adults demonstrate vergence adaptation to extra demands in maintaining eye alignment (in both convergent and divergent directions). This study asked whether vergence adaptation differed between hyperopes with and without a history of strabismus. Methods: The hyperopic participants were children and pre-presbyopic adults with spherical dquivalent refractive error ≥+3D in at least one eye and cylinder power ≤2D. They were compared to age-matched emmetropes. Vergence adaptation was assessed using changes in heterophoria after subjects viewed through a 6pd prism binocularly for four 1-min intervals. Eccentric photorefraction and Purkinje image eye tracking were used to monitor accommodation and eye alignment at 50Hz. All participants were tested with base in prisms requiring divergent adaptation. Results: Of 17 hyperopic participants (3.6-21.9 years of age, Mean 8.0, SD 4.9), 7 currently aligned with a history of strabismus showed -12% to 70% adaptation (Median 37%, IQR 2%-65%) and 5 generated < 50% adaptation; 10 hyperopes with no strabismus history adapted by -17% to 86% (Median 64%, IQR 29%-72%), with 3 showing < 50% adaptation. The age-matched emmetropes showed 2% to 118% adaptation (Median 72%, IQR 35%-81%), with 3 of 11 showing < 50% adaptation. Accommodation responses were monitored in each trial. Conclusion: These data suggest that strabismic hyperopes are more likely to have poor vergence adaptation. After a larger clinical trial, this factor could identify those at higher risk for refractive esotropia.

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53.429 **Stereo perimetry reveals peripheral loci mediating coarse stereopsis in macular degeneration** Preeti Verghese[1](preeti@ski.org), Saeideh Ghahghaei[1]; [1]The Smith-Kettlewell Eye Research Institute

The aim of this study is to explore the potential for binocularity and coarse steropsis in peripheral retina for individuals with central field loss due to age-related macular degeneration (AMD). We hypothesize that for patients with AMD, corresponding locations in the periphery where the retina has residual function can provide coarse stereopsis that is useful for eye-hand coordination. We developed a novel stereo perimetry method to evaluate coarse stereopsis across the visual field. Observers fixated a spot on a large-field stereoscopic display of random dots, and detected a target patch presented in a near depth plane. The target appeared along the cardinal and diagonal axes at an eccentricity from 0 to 25°, and its size was m-scaled for eccentricity. We used large steps (20 to 30 arc mins) to test peripheral locations at eccentricities of 15 to 25 degrees. For individuals with AMD, we performed monocular perimetry in a Scanning Laser Ophthalmoscope to estimate scotoma extent and preferred retinal locus (PRL), and used Optical Coherence Tomography to delineate the non-functioning fovea. This information was combined with a binocular scotoma mapping procedure to estimate intact regions with potential binocular overlap. These observers were tested primarily in their lower visual field. The four control participants showed intact stereopsis at all tested eccentricities. Of the two AMD participants, one had large scotomata with binocular overlap and measurable stereopsis at the PRL, whereas the other participant had smaller patchy scotomata in the two eyes with partial binocular overlap and no measurable stereopsis at the PRL. For stereo perimetry, both AMD participants showed coarse stereopsis at eccentricities greater than 10°, regardless of their ability to perceive depth at the PRL. Thus it appears that a relatively extensive region in the periphery can mediate coarse stereopsis that might be useful for eye-hand coordination.

Acknowledgement: R01EY027390

53.430 **The role of binocularly asymmetric peripheral field loss in abnormal binocular function in glaucoma** Marguerite M Devereux[1](mdevere@uab.edu), Rong Liu[1], MiYoung Kwon[1]; [1]Department of Ophthalmology, School of Medicine, University of Alabama at Birmingham, Birmingham, AL

Glaucoma is characterized by progressive loss of retinal ganglion cells and resulting visual field defects. Studies have shown that, even in early stages of glaucoma, binocular function such as stereopsis is significantly impaired (Essock et al., 1996). However, the mechanism underlying abnormal binocular function in glaucoma still remains unclear. Here we examined the factors that may undermine binocular function in glaucoma, particularly whether binocularly asymmetric peripheral field loss plays a significant role. The study included 17 glaucoma patients (mean age=65.76) and 17 age-similar normally-sighted individuals (mean age=60.12). Binocular function was assessed with a stereopsis test (Titmus Fly SO-001 StereoTest) in combination with a binocular fusion test (a Worth 4-dot test). For each subject, visual field loss (24-2 Humphrey Field Analyzer), visual acuity (ETDRS charts), and contrast sensitivity (Pelli-Robson charts) were also measured for each eye separately. Interocular differences of each functional measurement were computed to quantify the binocular asymmetry of vision loss. The interocular difference of visual field loss was further analyzed into four sub-regions: the foveal, parafoveal, perifoveal, and peripheral regions. Our data showed that compared to normal controls, glaucoma patients exhibited significantly poorer stereopsis (122 vs. 44 arcsec, $t(31)=-2.70$, $p=0.01$) and a larger interocular difference in visual field loss and contrast sensitivity (both $p< 0.05$), indicating binocularly asymmetric visual impairment in glaucoma. Furthermore, stereopsis results were significantly correlated with interocular differences of field loss in all the sub-regions beyond the fovea (all $p< .01$), but not with any of foveal interocular differences (all $p>.05$). Our results showed that stereopsis deficits in glaucoma can be largely attributed to binocularly asymmetric peripheral field loss. Our findings further suggest a significant role of peripheral vision in binocular function.

Acknowledgement: National Institutes of Health Grant R01EY027857

53.431 **Effects of short-term monocular deprivation on response time** Cherlyn J Ng[1](cherlyn.j.ng@gmail.com), Bart Farell[1]; [1]Institute for Sensory Research, Syracuse University, Syracuse, NY 13244

Deprivation during the critical period can permanently disrupt vision. Recent studies showed that vision could also be affected when adults were deprived for short durations (Lunghi et al., 2011; Zhou et al., 2013). However, instead of impairment, vision improved temporarily in the deprived eye. It might be expected that monocular deprivation creates a binocular imbalance that should be detrimental to stereopsis. However, a counter-argument is that stereo performance should nevertheless improve, because stereo channels become un-adapted during deprivation. Initial experiments that measured the effects of adult deprivation on stereoacuity were inconclusive, but an improvement in depth perception was noted in the temporal domain. This observation motivated the present study, which measured the time taken to make depth discriminations and the associated confidence levels. Subjects were stereo-normal adults whose stereoacuity was measured with square stimuli defined by disparity within dynamic random dot stereograms, immediately before and after deprivation. A dark patch was worn for 2.5h over the deprived eye, while the undeprived eye was free to view the environment. There was a reduction in response time to trials between 30s and the first minute post-deprivation. It returned to baseline thereafter. This reduction was accompanied by an increase in the reported confidence levels but not in stereoacuity. These results may be explained by two processes with different time-courses: the recovery from interocular imbalance just following deprivation, and then re-adaptation to stereocopic disparities.

53.432 **Eye fatigue in Augmented Reality at different vergence distances** Moqian Tian[1](m.tian@metavision.com), Joshua A Hernandez[1], Rosemary Le[2], Stefano Baldassi[1]; [1]Meta Company, [2]Psychology Department, Stanford University

Eye fatigue has been considered an important factor when designing visual content for Augmented Reality (AR). For AR devices that have a fixed focal plane, differences between the vergence distance of virtual content and the focal plane could cause eye strain, due to vergence-accommodation conflict (VAC, Shibata, T., Kim, J., Hoffman, D.M. & Banks, M.S., 2011). We investigated the effect of vergence distance on eye fatigue in an experimental setup. Eighteen Participants with normal vision were asked to read a book in an AR head-mounted display (HMD) for 45 minutes. Six participants read content rendered at the same depth as the focal plane (2.5D); six participants read content presented 0.9D farther than the focal plane; the remaining six participants read content presented

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1.8D farther than the focal plane. Retinal sizes of panel and font were matched in all three conditions. Before and after reading, participants were asked to rate the fatigue level of their eyes, necks, shoulders and backs. Their accommodation to near and far targets were also measured using a photorefractometer, and showed no change in accommodating to near and far targets after reading. Change of rating in eye fatigue after reading versus before reading showed significant difference between the nearest vergence distance (2.5D) and the furthest distance (0.7D, p=0.05), while there was no difference between the middle distance (1.6D) and the others. There was no difference in fatigue level on other body parts among the three conditions. VAC does not explain the our results since the biggest VAC showed the least eye fatigue. This suggests that in a visually straining task like sustained reading in AR, eye fatigue is dominated by vergence distance, with closer vergence causing the most eye fatigue.

Eye Movements: Saccade

Tuesday, May 22, 8:30 am - 12:30 pm

Poster Session, Pavilion

53.433 **Unifying the Quantification of Fixation Stability** Susana T.L. Chung[1](s.chung@berkeley.edu), Mehmet N. Ağaoğlu[1], Arun K. Krishnan[1,2]; [1]School of Optometry, University of California, Berkeley, [2]Envision Research Institute

Our eyes are in constant motion even when we attempt to hold our gaze steady. The precision in eye positions during fixation — fixation stability — is an index of oculomotor control, and has been proposed as a biomarker for early diagnosis of certain neurological and visual disorders. However, it is difficult to compare fixation stability across studies because of the different methodologies used for data collection and quantification. Our goal was to provide a single metric to quantify fixation stability. We measured eye positions during fixation of a 1° cross for multiple trials of 70s for 11 observers, using Eyelink II (250 Hz), Eyelink 1000 Plus (1000 Hz) and a scanning laser ophthalmoscope (eye positions sampled at 540 Hz). For each trial, fixation stability was calculated for epochs that grew in length, starting from the first 0.5s, in steps of 0.5s (0-0.5s, 0-1s, … 0-70s), using the bivariate-contour ellipse area (BCEA) that assumes normality of eye positions, and the iso-line area (ISOA) that does not assume normality. In general, both BCEA and ISOA increased with epoch length until they reached saturation. These data were modeled using an exponential function from which the time constant and the saturation level were derived. BCEA was always larger than ISOA. The BCEA/ISOA ratio differed with epoch lengths and eye-trackers but became identical (~1.1) across eye-trackers for epoch lengths beyond 20s. For 95% ISOA, time constants were statistically indistinguishable across eye-trackers (16.6–21.8s); while saturation levels differed by 3× (1525–4595 arcmin2). Normalizing these values by the imprecision (e.g. standard deviation) of the estimates across observers and trials for each eye-tracker removed the statistical differences. These findings suggest that a single metric can be used to unify the quantification of fixation stability for data obtained using different eye-trackers, facilitating the comparison of fixation stability across studies.

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53.434 **Classical conditioning of saccadic latencies using gap and overlap paradigms** 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

It is well established that a stimulus-onset-asynchrony between the fixation-target offset and the saccade-target onset considerably affects saccade latencies. A gap (fixation-target disappearing before the target-saccade onset) triggers short latency saccades. An overlap (fixation-target disappearing after the target-saccade onset) triggers long latency saccades. Here, we probe the possibility to control saccadic latencies using classical conditioning by systematically pairing a gap with one saccade direction and an overlap with the other. In classical conditioning (Pavlov, 1927), unconditional stimuli (US; e.g., food) –eliciting unconditional responses (UR; e.g., salivation)– are paired with initially neutral stimuli (NS; e.g., bell). After repeated pairing, the NS –then called conditional stimuli (CS)– come to elicit conditional responses (CR) comparable with the UR. We first associated a saccade direction (i.e. leftward or rightward, NS1 or NS2) with either a 150ms gap (US1) or a 150ms overlap (US2). We then introduced leftward and rightward probe-trials in which there was no SOA (CS1 and CS2; 20% of trials). Once steady state was observed, we did a return-to-baseline and then reversed the direction pairing. During baseline, we observed no difference in latencies across saccade directions. During training (6200 pairing trials on average), the gap and overlap (US) resulted in shorter and longer latencies (UR), respectively (median latencies differed by 156ms on average; all outside the 98% null hypothesis CI). For the probe-trials (700 trials), we observed considerable differences in latency distributions (CR; i.e., on average 58ms; all outside the 98% null hypothesis CI) consistent with direction pairing (CS). Interestingly, during the return-to-baseline sessions (200 trials), there was a slight maintenance of the CR (median latencies differed by 22ms). Our results demonstrate control of saccadic latencies by saccade direction using classical conditioning. This study further establishes that learned environmental contingencies affect the temporal allocation of saccades (Vullings & Madelain, 2017).

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53.435 **Temporal Precision of Directly Controlled Eye Movements** Jonathan P Batten[1](j.batten@bbk.ac.uk), Tim J Smith[1]; [1]Department of Psychological Sciences, Birkbeck, University of London

Recent eye movement timing models provide evidence for a two-component model: an autonomous stochastic timer that is optimally fast, and a mechanism for direct control that inhibits and cancels saccades subject to cognitive demand (e.g. CRISP, SWIFT, ICAT). This study statistically modelled adult fixation durations from a novel gaze-contingent visual search task, which allowed the isolation of these two components, represented as a bimodal distribution. From the modelled parameters we measured the proportion, distribution, and synchronisation of fixation durations. Participants were tasked to control when their eyes moved to match an isochronous auditory beat (IOI), whilst orienting sequentially around twelve circles (an elliptical shape). The currently fixated circle was in colour (red or blue) and the search task was identifying infrequent colour changes (tapping a trackpad). Each trial required a sequence of 180 circles and randomly played one of the eight IOI (from 300 to 1000ms in 100ms intervals), repeated twice. Mixture-modelling of the distributions converged on a bi-modal fit for all participants at each IOI. The first distribution had the shortest fixation durations (mu = 252ms) with small deviation (sigma = 65ms), both were minimally variant across IOI levels representing the profile of the saccadic timer. The size of the 'direct control' second distribution (lambda) increased significantly with the target IOI to asymptote at 50%. These directly controlled fixation durations and deviations significantly increased as the IOI increased. The proportion of fixations under direct control significantly predicted synchronisation performance (R2 = .47). Interestingly adding the participants finger-tapping ability did not increase the variance accounted for by lambda alone, which may indicate a shared fine-motor control mechanism. These data successfully profiled the two-components of eye movement timing, the saccadic timer and fixations under direct control, and provided a novel quantification of the proportion of fixations that can be directly controlled during active vision.

Acknowledgement: ESRC

53.436 **Saccadic temporal recalibration alters action and perception** Brent Parsons[1], Dunia Giomo[1], Domenica Bueti[1]; [1]Department of Neuroscience, SISSA

Studies of saccadic adaptation have primarily focused on manipulations in the spatial dimension. Shifting the location of the saccade target midflight leads to changes in the motor command (e.g. saccade amplitude) and affects subsequent perceptual judgments (e.g. localization). Surprisingly, significant gain reduction has been reported even when the shifted target is presented at post-saccade delays of up to 400ms (Shafer, Noto, & Fuchs 2000). Recent experiments manipulating only the temporal dimension, the delay between saccade landing and target presentation, have demonstrated changes in saccade peak velocity (Shadmehr, Orban de Xivry, Xu-Wilson, & Shih 2010). The current study investigates whether adapting

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to these artificially induced delays leads to temporal recalibration between action and effect. We test for recalibration using three behavioral tasks: sensorimotor synchronization, temporal order judgements, and duration comparisons. Evidence supporting saccadic temporal recalibration was found in all three experiments. Adapting to delayed feedback corresponded with shifts in saccade synchronization performance, a reversal in the perceived order of action and effect, and duration overestimation for visual stimuli presented at delays after saccade landing. The recalibration depended on the predictability of the visual effects and their temporal proximity to the end of the saccade. The results offer novel insight into the mechanisms underlying perceptual stability and link saccades to the more general phenomenon of motor-sensory recalibration.

53.437 **The time-course of trans-saccadic integration** Emma E.M. Stewart[1](emma.e.m.stewart@gmail.com), Alexander C Schütz[1]; [1]Allgemeine und Biologische Psychologie, Philipps- Universität Marburg, Marburg, Germany

As humans scan the surrounding world, each saccade brings an area of interest from low-resolution peripheral vision into high-resolution foveal vision. To maintain perceptual stability across saccades, these pre- and post-saccadic percepts must be integrated. Humans are able to achieve trans-saccadic integration in a near-optimal manner (Ganmor, Landy, & Simoncelli, 2015; Wolf & Schütz, 2015), however it is unclear if integration can happen as soon as the information from pre- and post-saccadic stimuli becomes available, or if integration requires the longer time usually taken to plan and execute a saccade. We measured the time-course of integration both at the saccade target and at a location between the target and initial fixation, to determine how long a stimulus needs to be presented for integration to occur. Participants were presented with oriented Gabors either pre-saccadically, post-saccadically, or both. The Gabor was presented for a variable time before and/or after saccade onset, to reduce the amount of time the stimulus information was available. Participants responded whether the Gabor was tilted clockwise or counter-clockwise. Discrimination performance was calculated for stimulus presentation durations ranging from 10-100ms, to create a continuous time-course of performance for pre-saccadic, post-saccadic and integration conditions. The results show that integration occurs even when the stimulus is only presented briefly. We compared integration performance with predicted performance for different cue combination models, showing that an integration model with early noise best describes integration performance for the majority of participants. The model comparison also shows that integration benefits are not due to increased exposure duration of either pre- or post- saccadic information alone. These findings suggest that integration can occur when only very little information is available before or after a saccade. Integration also seems to be accomplished by independent channels for pre- and post-saccadic information rather than a single, spatio-topic channel.

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53.438 **The effects of binocular instability and saccadic overshoot on the performance of educationally relevant tasks.** Matthew H Schneps[1,2](matthew.schneps@umb.edu), Marc Pomplun[1], Pavlo Antonenko[3], Do Hyong Koh[1], Richard Lamb[4], Andreas Keil[3]; [1]Computer Science, University of Massachusetts Boston, [2]Education Arcade, Massachusetts Institute of Technology, [3]Educational Technology, University of Florida Gainesville, [4]Learning and Instruction, University of Buffalo

It is generally thought that a stable fixational platform is critically important for vision, to reduce the deleterious effects of motion blur following a saccade. And yet, when the eye executes a saccade to image a target, the locus of the gaze briefly overshoots the target prior to fixation. The eye takes ~50ms to then settle on the target, executing movements resembling those of a damped harmonic oscillator before fixation is achieved. People appear to vary widely in the time it takes them to attain fixational stability following a saccade. Here, we consider the potential effects of binocular overshoot and instability on perception. On the one hand, poor binocular stability may hinder perception, perhaps by increasing reaction times in response to detail. On the other hand, given that there is evidence that small fixational movements enhance vision by pooling information from photoreceptors distributed on the retina, poor stability might enhance perception, especially toward the periphery where the distribution of ganglia is sparse. Given that the magnitude and duration of overshoot and instability vary widely, it should be possible to experimentally distinguish these competing cases. We examined these competing effects in two real world tasks important in education: (1) reading and (2) the detection of chiral asymmetry in depictions of organic molecules. While reading depends strongly on foveal acuity in decoding letters, it makes fewer demands on peripheral perception given the regularity of word arrays. In contrast, chirality detection makes strong demands on visual search and peripheral perception, but fewer demands on foveal acuity. Therefore, we would expect that those with poor binocular control will perform poorly in tasks such as reading, but perform well in tasks such as chiral detection, and expect the opposite for those who exhibit greater control. We report preliminary observations that support these hypotheses.

Acknowledgement: NSF SMA 1540888

53.439 **Effects of visual and tactile distractors on eye and hand movement curvature** Tom Nissens[1](tom.nissens@psychol.uni-giessen.de), Katja Fiehler[1]; [1]Experimental Psychology, Justus-Liebig University Giessen, Germany

Saccades are predominantly planned in a gaze-centered coordinate system, whereas, reaching movements mainly rely on a body-centered coordinate system. Previous research has shown that saccades and reaching movements are influenced by visual and tactile distractors. In the majority of studies movement targets were presented in the visual modality. For example, saccades towards a visual target curve away more from visual than tactile distractors. However, it is unclear whether this is due to an overlap in the target and the distractor modality or an overlap in the distractor modality and the effector-specific coordinate system.
In our study we asked the question whether saccades and reaches are differentially influenced by visual distractors when moving to a visual target and, similarly, whether they are differentially influenced by tactile distractors when moving to a tactile target. The experiment consisted of 4 tasks, performed in separate blocks. Participants had to reach or saccade towards either a tactile or a visual target. A visual or tactile distractor in the modality of the target was presented 350-600ms after the target, serving as a go-signal. In the tactile task, vibrotactile stimulation was applied to the index, middle, and ring finger of the left hand. In the visual task, visual stimuli were presented at the same location as in the tactile task. The target was always vertical above fixation with the distractors located left or right of the target. We found differential effects on movement parameters (curvature and endpoint deviation) of eye and hand movements depending on target/distractor modality. Our results indicate that the strength of distractor inhibition during movement planning depends on the overlap in the distractor modality and the effector-specific coordinate system.

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53.440 **Where am eye? Subjective gaze moves continuously across space before saccade onset** Meng Fei Ngan[1,2](bethngan92@gmail.com), Nina M Hanning[1,2], Heiner Deubel[2]; [1]Graduate School of Systemic Neurosciences, Ludwig-Maximilians-Universität München, Munich, Germany., [2]Allgemeine und Experimentelle Psychologie, Department Psychologie,Ludwig-Maximilians-Universität München, Munich, Germany.

People have a strong intuitive sense of where they are looking at, or where their gaze is directed. In contrast, previous reports found evidence for large deviations between subjective and objective gaze, in particular before saccadic eye movements. In the present study we asked how subjective gaze shifts when we make a saccade. Participants were asked to make a saccade towards an endogenously cued target 6° from fixation. A flash was presented for 25ms at any time between cue onset and 200 ms after their average saccade onset. This flash served as a temporal marker: After the saccade, participants indicated with a mouse pointer the location where they thought they were looking at when the flash occurred. If the flash occurred long before saccade onset or after the saccade, participants correctly reported their objective gaze. However, if the flash occurred between 250 and 0 ms before saccade onset, participants reported their gaze to be at locations intermediate between fixation and saccade target. In particular, subjective gaze was perceived closer to the saccade target

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the later the flash was presented. This demonstrates that people have the perception that their eyes are moving continuously from fixation to the saccade goal long before the actual start of the eye movement. It shows that people have very little knowledge about their actual eye position at any given moment in the vicinity of a saccade. They are unaware of the time when they make a saccade, and they cannot make use of the retinal position of objects to correctly indicate their objective gaze.

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53.441 **Pre-saccadic motion integration drives pursuit for saccades to motion apertures.** Sunwoo Kwon[1,2](s.kwon@rochester.edu), Martin Rolfs[3,4], Jude Mitchell[1,2]; [1]Brain and Cognitive Sciences, University of Rochester, [2]Center for Visual Science, University of Rochester, [3]Bernstein Center for Computational Neuroscience, Humboldt University of Berlin, [4]Department of Psychology, Humboldt University of Berlin

When a saccade is directed towards a translating target, smooth pursuit movements track the target from the moment of saccade landing, indicating that motion integration occurred prior to the saccade (Gardener and Lisberger, 2001). Since, prior to saccades, perceptual performance improves at the saccade target (Kowler et al, 1995; Deubel and Schneider, 1996; Rolfs and Carrasco, 2012), we hypothesized that saccades to a motion stimulus in a stationary aperture would drive post-saccadic pursuit movements due to the pre-saccadic selection of its motion. Participants performed a saccade to one of four motion apertures, cued by a central line. Apertures consisted of random dot fields (5 deg eccentricity and diameter, 100% coherent motion) moving in one of two randomly assigned radial directions tangential to the center-out saccade. Saccades exhibited a low gain (~10%) pursuit along the target's motion direction at saccade landing. These effects were driven by motion integration prior to the saccade, as we found consistent results when the motion stimulus offset occurred during the saccade. These effects grew as we reduced the spatial certainty of the aperture location, from a well-defined ring aperture, to no ring, or to a smoothed Gaussian envelope. Pursuit velocity increased with increasing stimulus speed with gain saturating at speeds higher than 10 deg/s. To examine what period prior to the saccade contributed to motion integration, we presented stimuli with random motion (0% coherence) that transitioned to coherent motion (either permanently or for fixed 100 ms epochs) around the time before saccade onset. We found that a minimum of 100 ms motion integration was necessary to observe an effect, with 150-50 ms before the saccade providing the strongest input. These results suggest that presaccadic attention engages motion integration for the saccade target that can be observed as an involuntarily low gain pursuit upon saccade landing.

53.442 **Curvature of saccades to moving targets corrects for initial directional errors** Alexander Goettker[1](Alexander.Goettker@psychol.uni-giessen.de), Doris I Braun[1], Karl R Gegenfurtner[1]; [1]Experimental Psychology, Justus-Liebig-University Giessen

Analyzing and predicting visual object motion is important for action and interactions. To successfully track a moving target, the oculomotor system has to take into account internal processing delays of 100 ms: the target will be already at a different location when the eyes start to move. To investigate predictive mechanisms of the oculomotor system under different conditions we measured tracking responses to vertical 10 deg target steps to the center, followed by linear ramp movements into one of the four cardinal directions (speed 10, 15, 20 deg/s). A single blob target appeared on a neutral gray background; it was white, gray or isoluminant red for testing under high and low luminance or color contrast conditions. We compared the dynamics of initial directions and curvatures of saccades for the different conditions and found that for high and low luminance targets initial saccade directions changed with their latencies, suggesting a continuous access to updated target movement predictions. For isoluminant targets, this directional updating was much weaker presumable due to poor motion signals. The comparison of the initial directions of saccades with the optimal direction based on the target position at saccade offset revealed that saccades to high and low luminance targets tended to initially overestimate target speeds. However, saccadic end points were quite accurate because saccadic curvatures scaled with initial directional errors for correction. These dynamic adjustments of saccadic movements suggest that the oculomotor system continuously updates predictions about target movements. In contrast to the classical view of saccade programming with a saccadic deadtime with limited correction possibilities from 80 ms before saccade onset, we found that corrections for the initial direction are still possible at least until saccade onset. Based on refined target movement predictions initial direction errors of saccades can still be corrected by adjusting their movement curvatures.

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53.443 **Investigating eye movements in enumeration using saccade-terminated trials** Jacob M Paul[1,2](jacobpaul88@gmail.com), Robert A Reeve[1], Jason D Forte[1]; [1]School of Psychological Sciences, University of Melbourne, [2]Experimental Psychology, Helmholtz Institute, Utrecht University

Recent evidence raises the possibility that numerosity is encoded by dedicated mechanisms in the human visual system, and subsequently processed by a specialized fronto-parietal network. Neural circuits implicated in generating saccadic eye movements partially overlap with this numerosity processing network. The overlap may reasonably imply eye movements play a functional role in enabling exact enumeration of small sets of objects, and underlie computation of visual numerosity. Alternatively, eye movements may reflect obligatory visual processing demands (i.e., object saliency, gaze heuristics, de-crowding). Here we systematically manipulated the opportunity to saccade to precisely specify the role of enumeration eye movements. Fifteen adults (11 naïve, 4 informed) enumerated random dot arrays under three conditions—(1) a novel saccade-terminated design where arrays remained visible until one, two or four fixations occurred; (2) a duration-terminated design where arrays were shown for 250ms, 500ms and 1000ms; and (3) a response-terminated design where arrays remained visible until a response. Enumeration was more accurate for saccade-terminated trials despite similar saccade latencies to duration-terminated trials: saccade-terminated trials lasted, on average [95% BCa CI], 316ms [289ms-356ms] (one fixation), 628ms [592ms-670ms] (two fixations) and 1320ms [1266ms-1380ms] (four fixations), while duration-terminated trials involved 0.46 [0.40-0.51] saccades (250ms), 1.06 [0.98-1.14] saccades (500ms) and 2.20 [2.07-2.34] saccades (1000ms). When participants were informed about how trials would terminate, saccade latencies shifted to match task demands. Fixation distributions were well-characterized by a simple filtering model of visual proximity grouping, while rotating saccade vectors to align with salient image locations accounted for variability in saccade trajectories. Our findings (1) validate the novel saccade-contingent procedure for investigating the functional role of saccades in enumeration, (2) emphasize the importance of simple visual grouping mechanisms for the computation of sets to enumerate, and (3) highlight the importance of incorporating the computational complexities of eye movements into models of numerical cognition.

53.444 **Frequency Content of Saccade Transients** Zhetuo Zhao[1](zzhaoaa@gmail.com), Naghmeh Mostofi[2], Jonathan D Victor[3], Michele Rucci[1]; [1]Department of Brain & Cognitive Sciences, University of Rochester, [2]Department of Psychological and Brain Sciences, Boston University, [3]Brain and Mind Research Institute, Weill Cornell Medical College

Humans and other species use saccadic eye movements to redirect the high-acuity fovea toward salient locations in a visual scene. In the course of shifting gaze, saccades necessarily introduce abrupt changes in the luminance signals impinging onto retinal receptors. Much work has been devoted to understanding how the visual system deals with the potentially negative consequences of saccade transients. However, it has also been argued that the saccade-induced reformatting of luminance patterns into temporal modulations is actually beneficial for visual encoding [Boi et al., 2013]. To explore this idea, we examined the frequency content of the visual signals delivered by saccades to the retina. We first recorded the eye movements of human observers at high resolution during free-viewing of natural scenes. We then reconstructed the visual input to the retina around the time of saccades and estimated its power in the joint space-time frequency domain. We show that the power redistribution resulting from saccades consists of two regimes. Below a critical spatial frequency, dynamic power (the power at non-zero temporal frequen-

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cies) impinging on the retina does not depend on spatial frequency. This happens because in this range, the saccade-induced conversion of spatial patterns into temporal modulations counterbalances the spectral density of natural scenes. Above the critical spatial frequency, the dynamic power follows the spectral density of natural scenes. Although this critical spatial frequency depends on saccade amplitude, there is a broad range of spatial frequencies for which the resulting spectrum is independent of saccade amplitude, thus providing a veridical representation of the visual scene independent of the specific saccade performed. We elucidate the origin of these effects, model their impact on the responses of neurons in the early visual system, and discuss their possible consequences for the establishment of visual representations during the saccade-fixation cycle.

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53.445 **Fixating an imaginary foveal stimulus increases microsaccades** Scott Watamaniuk[1,2](scott.watamaniuk@wright.edu), Jeremy Badler[2], Stephen Heinen[2]; [1]Dept. of Psychology, Wright State University, [2]The Smith-Kettlewell Eye Research Institute

Microsaccades point to an attended object, and we previously showed an attended object in the fovea elicits more microsaccades than one in the periphery. Here we ask if the microsccade increase was mediated by the position error to a foveal target, or if attention at the fovea alone is sufficient to modulate the saccadic mechanism. Observers fixated a 9-dot stimulus composed of a 6° circular array of eight dots, and a central one. In separate blocks of trials, they detected near-threshold luminance increases at either the central dot, or at a randomly selected peripheral dot, that occurred an average of 6 times within a 20 sec trial. An EyeLink 1000 recorded eye movements at 1000 Hz. Saccade rate was higher when the luminance-detection task was on the central spot than when it was on a peripheral one, suggesting that attention at the central spot was evoking microsaccades. We then tested if attention directed to the fovea alone, without a stimulus, is sufficient to evoke microsaccades. Observers viewed the center of the 8-dot peripheral array with no central element. In one condition, the attention task (luminance change detection) was imposed on the peripheral dots as before. In another condition, observers detected a near-threshold stimulus that appeared in the center with the same frequency as the peripheral luminance change. We found that microsaccade rate was higher when observers attended the center even during epochs when no stimulus was present. Thus, foveating an imaginary stimulus still engaged the saccadic system. Analyzing microsaccade direction, more saccades were directed toward the center when the imaginary stimulus was attended, indicating that physical position error is not necessary for the generation of "corrective" microsaccades. The results suggest that the frequency of spontaneous microsaccades in the absence of a stimulus can reveal if attention is at the fovea.

Acknowledgement: NIH-1R01EY021286

53.446 **The human saccadic adaptation field across time** Eef Joosten[1,2](pointer1313@gmail.com), Therese Collins[1,2]; [1]Université Paris Descartes, Sorbonne Paris Cité, Paris, France, [2]CNRS (Laboratoire Psychologie de la Perception, UMR 8242), Paris, France

Adaptation of saccadic amplitude is induced by displacing the target during eye movements (McLaughlin, 1967) and saccade amplitude matches the post-saccadic target location. This oculomotor plasticity is specific to the adapted saccade motor vector and transfer to other vectors is proportional to their proximity to the adapted vector (Watanabe, Noto, & Fuchs, 2000; Collins, Dore-Mazars, & Lappe, 2007). The aim of this study was to see how the temporal window of transfers to other saccades evolves over time. We adapted horizontal saccades of 12 or 16 dva (15 per condition). Observers were instructed to follow a dot which could appear 4,6,8,10,12,14,16,18 or 20 dva to the left or right in the Amplitude Test condition. In one condition, we adapted the 12 dva saccade by stepping the dot backwards with 3 dva and in another the 16 dva saccade by stepping back with 4 dva. In the Direction Test condition, the dot always appeared at 12 dva but in an angle of 0, 45, 90, 135, 180, 225, 270 or 315 degrees . In the pre- and post-adaptation stages, the dots disappeared upon saccade detection. In the adaptation stages, the dots disappeared except for the adapted vector. The adaptation stimulus was presented about 8 times more frequently as the other stimuli. We show that adaptation transfers to other vectors as a function of the difference between adapted and tested vectors both in amplitude (Figures 1 and 2) and direction (Figure 3). Current analyses, aimed at these early stages, reveal differences in time courses of separate vectors (e.g., the time course for the 12 dva Amplitude Test condition was less steep as the 12 dva in the Direction Test which was, in turn, correlating with the 16 dva Amplitude Test. We aim to distinct between the transferability of information stored in motor maps.

53.447 **Memory-guided saccades to visual stimulus sequences: influence of set-size and spatiotemporal structure on recall accuracy** Sharmini Atputharaj[1,2,3](atpshar@my.yorku.ca), David C Cappadocia[1,3], J. Douglas Crawford[1,2,3,4,5]; [1]Centre for Vision Research, York University, Toronto, ON, Canada, [2]Vision Science to Applications (VISTA), York University, Toronto, ON, Canada, [3]Department of Kinesiology & Health Science, York University, Toronto, ON, Canada, [4]Department of Biology, York University, Toronto, ON, Canada, [5]Department of Psychology, York University, Toronto, ON, Canada

Saccades have been used extensively as a tool to measure cognitive processes such as visual working memory (VWM). The goal of this study was to identify the effect of spatiotemporal structure on performance in memory-guided saccade sequences. Six participants (ages 21-34) were presented with a sequence of targets on a 5x5 LED display encompassing 20°x20° of visual space, then they were told to fixate the central LED and memorize a sequence of 3-6 targets presented peripherally. The spatiotemporal structure of this sequence could be (1)structured (recognizable shape and temporal order), (2)semi-structured (recognizable shape with random temporal order) or (3)unstructured (random shape, random temporal order). Following offset of the fixation light, subjects saccade toward the remembered spatiotemporal sequence of targets. Presentation and execution of saccades were in complete darkness. ANOVA results showed significant main effects: 1)saccade errors were greatest for unstructured conditions and 2)targets presented earlier in sequence were recalled with higher accuracy than later targets. There were also interactions between spatiotemporal structure and 1)set-size (structure provided greater benefits for larger set-sizes) and 2)order (structure provided more benefits for early targets). However, in this experiment it was difficult to disentangle errors of target choice, errors of target position memory, and saccade motor errors. Therefore, in Experiment 2, we added a continuously-displayed placeholder array outlining the 25 possible target locations, thus providing additional allocentric cues for target selection in the recall/motor execution phase. Preliminary results (n=4) for Experiment 2 show similar trends with respect to the effect of spatiotemporal structure, however, the presence of allocentric cues seems to greatly improve the recall accuracy compared to Experiment 1. Overall, these results show that VWM capacity is improved by the presence of spatiotemporal structure for sequences that had egocentric and allocentric spatial representation, but that this interacts with other factors such as set-size.

Acknowledgement: Canadian Institutes for Health Research

53.448 **Visual-motor transformation in the multiunit activity of the frontal eye fields (FEF) during the head-unrestrained gaze shifts in rhesus monkeys** Vishal Bharmauria[1](bhav2501@yorku.ca), Amirsaman Sajad[2], Xiaogang Yan[1], Hongying Wang[1], John Douglas Crawford[1]; [1]York University, [2]Vanderbilt University

Multiunit activity represents the average spiking of a neuronal population recorded within the vicinity of a microelectrode. There is increasing consensus that the multiunit activity contains information about the spatial structure of the stimulus or the task involved. Indeed, recently, using single neuron electrophysiology and a unique toolbox developed in our laboratory, we have shown that the frontal eye field (FEF) and the superior colliculus (SC) visual neurons encode the target in eye coordinates (Te) and the motor response describes the gaze in eye coordinates (Ge). Here, we sought to examine the spatial structure embedded in the multiunit activity of the FEF neurons which are central to visual-motor transformation in the 3-D gaze system. Neuronal recordings with tungsten microelectrodes were performed in the FEF of two rhesus monkeys which were trained to make centrifugal gaze shifts (to the remembered target) in a delayed memory task, either in the presence or absence of an allocentric landmark. Using the same model-fitting approach as for the single neurons, we fitted and distinguished different egocentric models embedded in the multiunit activity of the FEF neurons. The preliminary analyses show that the visual burst of the multiunit response (n=11)

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also encodes the target relative to the eye (Te), whereas the multiunit motor responses (n=8) encode the gaze in the eye coordinates (Ge). This suggests that 1) the receptive fields of neurons comprising the multiunit are overlapped and 2) the multiunit activity can also be used as a reliable marker of the visual-motor transformations in the FEF, if one is unable to sort the single units from it. Further analysis is targeted on analyzing more multiunit sites and the same analysis in the SC and supplementary eye fields (SEF).

Acknowledgement: CIHR

53.449 **Reading from right to left: oculomotor adaptations** Johan Chandra[1](jochandr@uni-potsdam.de), André Krügel[1], Ralf Engbert[1]; [1]Experimental and Biological Psychology, University of Potsdam

Integration of sensory processes and prior knowledge for optimal oculomotor behavior can be observed in eye movement control during reading. An indication that prior knowledge is used in saccade planning during reading can be observed in the systematic shift of saccadic within-word mean landing position as a function of launch-site, the launch-site effect (McConkie et al., 1988; Engbert & Krügel, 2010). When reading condition changes, prior knowledge provides stability under sensory noise, while flexibility for adaption is necessary to generate optimal saccadic behavior. Here we present results of reading experiment in which normally written words are read from right to left. While no changes were observed in temporal eye-movement measures, we observed notable changes in spatial aspects of eye-movement. When reading direction is the opposite of writing direction, the launch-site effect decreases substantially compared to the one observed in normal reading. The results are in line with the view that oculomotor process is adaptive to unusual reading condition.

Acknowledgement: DFG

53.450 **Reduced sensitivity to trial pacing in Parkinson's disease saccadic eye movements.** Mark Harwood[1,2](mharwood@sci.ccny.cuny.edu), Annabelle Blangero[2]; [1]University of East London, UK, [2]City College of New York, USA

The involuntary and stereotyped kinematics of saccadic eye movements have inspired many optimisation models, and allowed for saccades to be a useful clinical diagnostic. Faster velocity, "supra-optimal", saccades have been difficult to elicit and of more limited clinical use (e.g. opsoclonus). Small velocity increases (~5%) can be elicited via explicit reward paradigms. Recent, but limited data in young healthy adults, also suggests that faster saccades can be facilitated by simply increasing the pacing of trials (reduced inter-trial intervals). One explanation of this pacing effect is that the accumulated implicit reward of landing on target increases with faster pacing, and that this is mediated by dopaminergic neurons in the basal ganglia. We asked whether effects of pacing on saccadic velocities are decreased in Parkinson's disease as reward sensitivity is impaired in these patients. We recorded saccades from 10 young controls, 10 age-matched controls and 10 Parkinson's disease patients to targets that stepped to a new location at intervals ranging from 0.1-1.1s after the primary saccade to the preceding target location. Healthy young and old controls showed small, but robust increases in saccade velocities with increased trial pacing (+3.7% and +3.6%, respectively), comparable to previously reported findings. Interestingly, there was no significant difference with age. In contrast, Parkinson's disease patients showed no velocity modulation with trial pacing (pacing slope = -0.02, $p > 0.05$), suggesting the implication of the reward system in the increased saccade pacing effect. We also conclude that changes in saccade velocity with pacing may usefully distinguish Parkinson's disease from healthy controls.

Attention: Tracking

Tuesday, May 22, 8:30 am - 12:30 pm

Poster Session, Pavilion

53.451 **A capacity limit for the rapid parallel selection of multiple target objects** Anna Grubert[1](anna.k.grubert@durham.ac.uk), Martin Eimer[2]; [1]Department of Psychology, Durham University, [2]Department of Psychological Sciences, Birkbeck, University of London

We recently employed the N2pc component as a real-time electrophysiological marker of attentional selectivity to demonstrate the existence of a fast mechanism for the independent parallel selection of two colour-defined target objects at different locations. When these objects were presented in rapid succession in different displays (with SOAs between 10 and 100 ms), both triggered N2pc components of similar size and with onset latencies that matched the SOA between the two displays, indicating two parallel attentional selection processes with independent time courses (Eimer & Grubert, 2014; Grubert & Eimer, 2015, 2016). Here, we investigated whether these parallel processes can operate for more than two targets simultaneously, given that multiple-object tracking studies suggested that up to four attentional foci can be maintained in parallel (Cavanagh & Alvarez, 2005). In Experiment 1, four horizontal colour targets could appear in four successive displays, each separated by a 10 ms SOA. Trials where one of the four targets appeared on the vertical midline were also included. These were subtracted from ERPs on all-horizontal target trials, to extract N2pcs separately for each of the four targets. All targets triggered reliable N2pcs, with onset latencies matching the SOA between displays, suggesting that four objects can be selected independently and in parallel. In Experiment 2, the same procedures were used, but now with eight targets in eight consecutive displays. All eight targets elicited N2pc components that approximately matched their temporal position, but N2pc amplitudes were reduced by 50% relative to Experiment 1. This difference suggests that feature-based attentional selection mechanisms can operate in parallel for up to four items, although a lower capacity limit remains possible. We discuss the implications of these results for models of attentional control.

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53.452 **Strategic Search for Camouflaged Targets: Training Type Impacts Oculomotor Behavior** Joanna Lewis[1](joanna.lewis@knights.ucf.edu), Dawn Sarno[1], Ada Mishler[1], Alyssa Hess[2], Corey Bohil[1], Art Kramer[3], Mark Neider[1]; [1]University of Central Florida, [2]Nuance Communications, [3]Northeastern University

One's ability to locate a target decreases as a function of similarity to the environment, such as when a target is camouflaged (e.g., Bravo & Farid, 2004; Neider & Zelinsky, 2006; Wolfe et al., 2002). Short-term training improves the ability to detect both trained and novel camouflaged targets in artificial scenes (Boot, Neider, & Kramer, 2009; Neider et al., 2013). However, it is less well known whether training in camouflage detection can be improved in natural scenes and over longer training durations. Here we present manual response and oculomotor data from a larger study in which we assessed the extent to which participants could be trained to better detect camouflaged targets in natural scenes over 14 training sessions, and whether that training transferred to novel nature scenes with similar targets. We utilized three training groups: adaptive camouflage (staircase method with changes in target size), massed camouflage (blocked sessions, target size decreasing across sessions), and control (T/L search, increasing set-size). All reported results are specific to the sessions assessing transfer of training to camouflaged targets in novel search scenes. We found a benefit of training for massed and adaptive conditions in response time and accuracy. To better understand the dynamics underlying training benefits we used a median split to divide participants into groups of learners and non-learners (i.e., steep vs. shallow slopes). We found that learners in the massed training group improved in accuracy and response time at transfer more so than adaptive or control. Furthermore, adaptive trainees displayed a significant shift in strategy after training as reflected by longer, but less frequent fixations. For participants in the massed training group, those identified as learners had a reduction in initial fixation duration. Overall, training improved search performance through changes in oculomotor strategy, but training type affected the changes in strategy.

Acknowledgement: Office of Naval Research

53.453 **Your hidden capacity revealed! The Multiple Object Awareness (MOA) paradigm.** Chia-Chien Wu[1,2](cchienwu@gmail.com), Jeremy M Wolfe[1,2]; [1]Brigham and Women's Hospital, [2]Harvard Medical School

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Most of previous studies of position tracking, identity tracking or change tracking produce capacity estimates in the limited range of 2-4 items. However, the standard design of these experiments systematically underestimates true capacity. Suppose, after monitoring a set of unique objects, all objects are hidden behind identical disks and you are asked, "Where was the cat?". In a standard experiment, if you click on the wrong item, you are simply wrong; but, if you knew that it was one of two or three items, evidence for that knowledge would be lost. To measure the capacity of this more diffuse Multiple Object Awareness (MOA), we asked observers to keep clicking until they found the target object. More specifically, observers were asked to track the identities of 16 unique cartoon animals. Using the Reciprocal Velocity Obstacle crowd simulation algorithm of VanDenBerg, et al (2011), animals moved continuously within an imaginary window without colliding with each other or with obstacles. After a random tracking interval of 7-20 sec, all animals stopped and were hidden by grey discs. A target animal was designated and observers were instructed to click on disk until they uncovered the target location. Then, observers clicked again, restarting the motion and continuing the same tracking task. Classic identity tracking capacity was calculated by analyzing the accuracy of the first click. This yielded a sensible K = 2.68. Multiple Object Awareness (MOA) is calculated from the total clicks needed to discover the target. Random guessing would require clicking half the objects, on average. In fact, observers need fewer clicks, consistent with K = 6.6. We believe that MOA gives a more accurate (and optimistic) estimate of how much observers know about the locations of objects in dynamic scenes.

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53.454 **Object size affects multiple object tracking performance (but not via frequency of close encounters)** Shanmukha A Upadhyayula[1](supadhy6@jhu.edu), Jonathan I Flombaum[1]; [1]Department of Psychological & Brain Sciences, Johns Hopkins University

Multiple object tracking (MOT) is a useful paradigm for understanding the causes of performance limits in visual cognition. Among the several debates about the causes of performance limits in the task, one point of consensus is that the frequency with which objects approach close to one another —close encounters— is a primary factor. A corollary implication is that display factors which increase encounter frequency should impair performance, as has been demonstrated, for example, in the cases of speed and trial duration. A feature that should have a similar effect is object size: in a fixed space larger objects should be near one another more frequently. Surprisingly object size has never been investigated as a factor that interacts with performance. We therefore manipulated object size in our experiments. Participants performed a standard MOT task: track and later identify targets among a set of featurally indistinguishable nontargets. In the experiments, we varied the sizes of the discs tracked, within participant, as well as speed and tracking load. But we observed that smaller objects were actually (and significantly) more difficult to track than larger ones. As a sanity check, we computed the frequency of close encounters as a function of size, finding that bigger items were indeed more likely to collide with one another. These results are important because they undermine the assumption that objects are tracked as though they are single points, an assumption that has been implemented in computational models of the task (including our own). We therefore propose an updated model, which incorporates object size in the uncertainty associated with tracking object positions.

Acknowledgement: NSF BCS 1534568

53.455 **Examining the benefits of training attention with Multiple Object-Tracking for individuals diagnosed with a neurodevelopmental condition: A cross-over, cognitive training study** Domenico Tullo[1,2](domenico.tullo@mail.mcgill.ca), Jocelyn Faubert[3,4], Armando Bertone[1,2]; [1]McGill University, [2]Educational and Counselling Psychology, [3]Université de Montréal, [4]École d'Optométrie

Multiple Object Tracking (MOT) is a robust measure of visual attention that accurately targets and isolates selective, sustained, dynamic and distributed attention. Given these characteristics, the present study assessed the potential to train attention in individuals diagnosed with a neurodevelopmental condition (NDC) using a MOT task that adapted to the participants' capability by adjusting object velocity after each trial. The attentional capacity of 96 children and adolescents, diagnosed with either Autism Spectrum Disorder, ADHD, Intellectual Disability, or other genetic based NDCs was assessed at baseline using the clinically validated Conners Continuous Performance task 3rd edition (CPT-3). Participants were then randomly assigned to one of two cross-over groups: the MOT training group (n=32; MIQ=79), an active control group that played a math-like strategy game (n=32; MIQ=75); or a passive control group (n=32; MIQ=80). Following 15 training sessions (3 times per week for 5 weeks), only the experimental MOT training group showed significantly improved CPT-3 scores when compared to baseline. There were no post training improvements for active and passive control groups. The MOT and active control group then crossed-over and switched treatment conditions. Following the subsequent 15 training sessions after cross-over, post-test improvement on the CPT-3 scores was once again once found for the MOT training group. Additionally, there were no differences in training gains between neurodevelopmental conditions. The results from the cross-over design demonstrates that training attention was directly related to MOT, while controlling for Hawthorne effects or expectancy bias (i.e., active control) and test-retest effects (i.e., passive control). Overall, these findings highlight the benefit of training attention with MOT by specifically and accurately targeting attention for children and adolescents with a NDC and concurrent attentional difficulties. Moreover, using a non-verbal task, void of context, or any social stimuli is optimal when training attention with an atypically developing population.

53.456 **Attention to objects at different depths is affected by their layout in depth and the plane of fixation, but is unaffected by aging.** Eugenie Roudaia[1,2](roudaia@mcmaster.ca), Maya Labrèche[1], Delphine Bernardin[1,3], Aarlenne Z Khan[1], Jocelyn Faubert[1]; [1]École d'optométrie, Université de Montréal, [2]Psychology, Neuroscience & Behaviour, McMaster University, [3]Essilor Canada Ltd.

Previously, we found that attending to different depth planes is more difficult compared to the same depth plane, only when the attended objects are further away from fixation (Roudaia et al., VSS, 2017). Here, we examined how the spatial layout of objects in depth and the plane of fixation affect dynamic attention capacity, both in younger and older adults. Stimuli comprised two virtual rectangular prisms arranged one above the other, each containing four tennis balls. While maintaining central fixation between the two zones, participants tracked two of the four balls in each zone as they moved for 6 s. The placement of the two zones in depth varied across four conditions: the two zones were either in the same depth plane (both near or far), or were at different depth planes (top near and bottom far; top far and bottom near). Depth was conveyed via stereo disparity and relative size cues. The fixation point location also varied, being at the same depth plane as the top zone, bottom zone, or both. When both zones were in the same depth plane, tracking accuracy was similar for the near and far conditions. When fixating near, performance declined when the top zone was far and even more so when the bottom zone was far. When fixating far, performance was unaffected when the bottom zone was near, whereas it declined when the top zone was near, especially in the older group. In sum, distributing attention in depth is easiest when the objects in the upper visual field are far and those in the lower visual field are near and proximal to fixation, consistent with ecological conditions. The pattern of results was similar across both age groups, indicating that aging does not impair the control of attention in depth.

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53.457 **Eye Movements Indicate Implementation of Mental Simulation to Assess Future Object Movement** Aarit Ahuja[1](aarit_ahuja@brown.edu), David Sheinberg[1]; [1]Neuroscience Graduate Program, Brown University

We regularly interact with objects in our environment in a way that requires some understanding of how objects naturally move. Little is known, however, about how we extrapolate the movements of visually perceived objects. Some theories propose that movements are experienced via mental simulation, allowing an object's trajectory to be internally generated even before it begins to actually move. We examined this possibility by asking human participants to make judgments about certain visual scenes. Specifically, participants (n = 11) were shown a display with a suspended ball located near the top and various randomly arranged "planks" spanning the middle. At the bottom were two possible "catchers" that the ball could fall into. Participants were asked to determine into which of the two catchers the ball would land, if it were to be dropped. This required subjects to assess which planks the ball would hit on its way down, and how the ball would bounce upon hitting a plank. Participants indicated their choices by pressing one of two buttons. Subjects' eye movements were tracked (Eyelink 1000) as they performed this task. We found that reaction times were correlated with the number of planks hit, as well as the total distance travelled by the ball. This finding supports the idea that subjects employed mental simulation, as these two measures would affect simulation complexity and length respectively. We also found that subjects' eye movements prior to their response mapped out a path that overlapped significantly with a computer-generated true trajectory for the ball on a given trial. Lastly, we could predict participants' responses to these displays using the eye movement information from the static "pre-movement" period. Together, these findings provide evidence for mental simulation of natural motion, and pave the way for future investigations of this phenomenon at a neural level in animals.

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53.458 **Measuring the Effect of Event Boundaries on Visuospatial Attention During Event Perception** Ryan V Ringer[1](rvringer@ksu.edu), Zachary Throneburg[1], Bretney Belvill[1], Amber Craig[1], Sarah Albert[1], Nicole Bartel[1], Anna Cook[1], Lester C. Loschky[1]; [1]Department of Psychological Sciences, Kansas State University

Event Segmentation Theory posits that efficient perception and memory of real-world events is enabled by breaking events into smaller "chunks" of information. These chunks of information exist at fine and coarse-grained levels, and are influenced by bottom-up and top-down event characteristics, respectively. Event boundaries represent transitions between event segments, signifying when meaningful units of information have ended. Prior research suggests that covert attention is impaired during event boundaries, however where and when these changes in attention occur are still unclear. Additionally, some eye-movement research suggests the ambient processing mode occurs at event boundaries, while focal attentional processing occurs within events. This study measured covert attentional breadth with gaze-contingent presentations of Gabor patches while participants watched videos of real-world events. Gabors were presented at 0, 4.5, or 9 degrees from the fovea, and were time-locked to appear at times before and after event boundaries, as well as non-boundary times. Furthermore, the Gabor patches were m-scaled in size and SOAs (processing time) were thresholded to ensure equal performance across the visual field in the absence of attentional modulation. The results demonstrated unique effects of coarse versus fine event boundaries on attention. For coarse event boundaries, attention was broadly distributed before the boundary and rapidly narrowed after the boundary passed. Conversely, for fine event boundaries, attention was weakly tunneled prior to the boundary, and slightly broadened after the boundary. Non-boundary (i.e., control) Gabor presentations revealed that attention was strongly tunneled during the middle of the event. Thus, the data supports the hypothesis that attention shifts from ambient to focal processing from boundary to non-boundary event periods. Additionally, coarse event boundaries might also reflect anticipatory, top-down guidance of attention (e.g., goal monitoring, prospective memory), whereas fine event boundaries may reflect reactive, bottom-up capture of attention (e.g., motion, object manipulation, etc.).

Attention: Temporal

Tuesday, May 22, 8:30 am - 12:30 pm

Poster Session, Pavilion

53.459 **Temporal Dynamics of Visual Attention Allocation** Seonggyu Choe[1](sgchoe@unist.ac.kr), Jongmin Moon[1], Oh-sang Kwon[1]; [1]Dpartment of Huan Factors Engineering, Ulsan National Institute of Science and Technology (UNIST), Republic of Korea

Visual attention to a specific space and time improves performance on the focused point (Carrasco, et al., 2004; Correa et al., 2005). It is expected that benefits of the focused attention partially spread out to adjacent area in space and time. The performances for spatially adjacent objects indeed improve depending on the distance from the focused location (Downing, 1988). However, the influence of attention on temporally adjacent objects is not known. METHODS: In Experiment 1, we presented a visual countdown from 5 to 1 with one-second interval to focus attention at one second after the countdown. A Gabor-patch appeared after the countdown with inter-stimulus-interval (ISI) randomly selected from nine ISIs between 0.7 and 1.3 sec. Subjects reported the orientation of the Gabor-patch. Contrast threshold was measured for each ISI. In Experiment 2, we repeated the procedure of Experiment 1 with an additional task to report the perceived duration of ISI relative to the countdown interval (one sec) after the orientation judgment task. The bias in time perception was measured to examine the effect of perceived time on visual performance. RESULTS: Contrast thresholds were significantly different across ISI ($F(6,84)=9.121, p< 0.001$) manifesting the effect of temporal attention. Interestingly, the contrast thresholds for ISIs between 0.7 and 1 sec were virtually constant (slope=-0.0031), whereas the contrast thresholds for ISIs after 1 sec gradually increase (slope=0.0279) showing asymmetric decay of temporal attention and significant difference in the bootstrap test ($t(14)=-23.7643, p< 0.001$). Results of Experiment 2 show that subjects perceived 1.2 sec as 1 sec implying that the improved performances on shorter ISIs are not due to the biased time perception. CONCLUSIONS: Results show that temporal attention decays faster after the focused point than before unlike spatial attention. A model controls temporal attention based on the conditional probability of future events can explain the results.

53.460 **Temporal attention improves perception at foveal and parafoveal locations equally** Antonio Fernandez[1](af3036@nyu.edu), Rachel N Denison[1,2], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Purpose: Discriminability across our visual field is heterogeneous. It is greatest at the fovea and diminishes with eccentricity. Perception also varies across isoeccentric locations with different polar angles, a phenomenon known as performance fields: perception is best at the horizontal meridian, worst at the upper vertical meridian, and intermediate at the lower vertical meridian. Spatial attention improves discriminability at different isoeccentric locations to the same degree, but it equates speed of processing, thereby preserving performance fields for discriminability but eliminating them for speed of processing. Here we asked whether temporal attention benefits performance in a similar or differential way across the visual field. Methods: Participants (n=8) discriminated the orientation of one of two grating patches presented serially at foveal or parafoveal (4° eccentricity) isoeccentric locations (right horizontal meridian and upper vertical meridian). Each target was tilted clockwise or counterclockwise about the vertical or horizontal axis independently of the other. Spatial location varied across sessions. Prior to stimulus presentation participants were pre-cued to attend to the first target (high tone), the second target (low tone), or both targets (both tones together; neutral cue). After presentation of the second target, a response cue instructed observers which target to discriminate, first or second, with equal probability on neutral trials. On valid trials, the response cue matched the pre-cue. Results: Temporal attention improved performance (d'), more so for the first than second target, and shortened RT to the same degree across all targets and locations. Critically, the magnitude of the attentional effect did not differ across spatial locations. Conclusion: Temporal attention benefited discriminability and shortened RT at foveal and different parafoveal locations equally, providing evidence that temporal attention is uniformly effective across the visual field. Performance fields are preserved with temporal orienting of attention.

Acknowledgement: NIH RO1-EY019693

53.461 **Sustained spatial attention can affect feature fusion** Ilanit Hochmitz[1](ilanit57@gmail.com), Marc M Lauffs[2], Michael H Herzog[2], Yaffa Yeshurun[1]; [1]Psychology Department, University of Haifa, Israel, [2]Laboratory of Psychophysics, Brain Mind Institute, EPFL, Lausanne Switzerland

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When two verniers are presented in rapid succession at the same location feature fusion occurs. Instead of perceiving two separate verniers, participants typically report perceiving one fused vernier, whose offset is a combination of the two previous verniers, with the later one slightly dominating. Here, we examined the effects of sustained attention – the voluntary component of spatial attention – on feature fusion. One way to manipulate sustained attention is via the degree of certainty regarding the stimulus location. In the attended condition, the stimulus appeared always in the same location, and in the unattended condition it could appear in one of two possible locations. Participants had to report the offset of the fused vernier. Experiments 1a and 1b measured attentional effects on feature fusion with and without eye-tracking. In both experiments, we found a higher rate of reports corresponding to the offset of the second vernier with attention than without attention, suggesting that attention strengthened the final percept emerging from the fusion operation. In Experiment 2, we manipulated the stimulus duration to encourage a final fused percept that is dominated by either the first or second vernier. We found that attention strengthened the already dominant percept, regardless of whether it corresponded to the offset of the first or second vernier. These results are consistent with an attentional mechanism of signal enhancement at the encoding stage.

53.462 **Get ready! Mental alertness enhances perceptual processing and visual awareness** Mathieu Landry[1](mathieu.landry2@mail.mcgill.ca), Jason Da Silva Castanheira[1], Amir Raz[1]; [1]Montreal Neurological Institute, McGill University

A growing body of research highlights that our ability to predict future events shapes our subjective experience of the world. For example, recent studies show that phasic alertness – i.e., increased response preparation and heightened attention following a warning signal – influences perceptual awareness. Following this research trajectory, we investigated how mental alertness and response preparation interface with visual awareness. In particular, our goal was to unravel the specific influences of pre-stimulus processes involved in response preparation over visual awareness. To that end, participants completed a target discrimination task where we combined a temporal cueing approach with a backward masking strategy, while we recorded brain activity using 64 channels electroencephalography. A temporally predictive cue preceded the target event for half of trials, thereby allowing participants to reliably estimate the latency of the target event. For each trial, participants provided an objective response, where they indicated the orientation of the target (left vs. right), as well as a subjective judgment about its visibility (seen vs. unseen). Our results show that heightened mental alertness benefits both performance (i.e., improved ideomotor response and perceptual sensitivity) and perceptual awareness (i.e., increased reports of visibility). At the neural level, cueing prompted opposite effects over the magnitude of power in frontal theta and occipital alpha oscillations, two neural responses that likely index discrete brain processes linked to response preparation and mental alertness. Consistent with our behavioral results, findings also revealed that increased alertness modulated the amplitude of the P3b, an event-related potential linked to perceptual awareness. Finally, using a computational model, we found that these effects likely reflect the influence of alertness over the rate of perceptual evidence accumulation, thereby implying that alertness primarily influence awareness through perceptual processes.

Acknowledgement: NSERC

53.463 **Temporal attention enhances vision by a combination of signal amplification and noise reduction** Luis D Ramirez[1](luisdr@bu.edu), Sam Ling[1]; [1]Psychological and Brain Sciences, Boston University

How does attending to a moment in time augment vision? In this study, we examined the mechanisms by which temporal attention – the allocation of attention to a specific moment in time – enhances visual sensitivity. To do so, we employed an equivalent noise framework. Under this framework, one's visual sensitivity can be enhanced primarily in two ways: signal amplification and noise reduction. Benefits of signal amplification arise only when there is very little external noise in a visual scene, whereas benefits of noise reduction arise only when there is ample noise to reduce in a visual scene. To examine whether temporal attention improves perceptual performance by means of signal amplification, noise reduction, or a combination of both mechanisms, we assessed perceptual sensitivity for discriminating a target stimulus embedded in various levels of external noise. Specifically, observers performed a fine-orientation discrimination task, reporting the clockwise or counter-clockwise orientation of a sinusoidal grating that appeared at a random time-point within a window of a trial. Temporal attention was evoked by the random onset of an auditory pre-cue within a trial (focused attention condition), and compared to a condition in which no information was given regarding stimulus onset (distributed attention condition). Target stimuli were embedded in Gaussian noise of ten contrast levels (0-60% contrast). To evaluate the noise regime in which attention had its greatest effects, contrast thresholds were determined for each external noise level and attention condition. Results revealed large benefits of temporal attention across all external noise levels, implicating a combination of signal amplification and noise reduction mechanisms sub-serving the benefits of temporal attention.

53.464 **The Effects of Rhythmic Structures on Visual Attention Parameters** Nir Shalev[1](nir.shalev@wolfson.ox.ac.uk), Anna Christina Nobre[1,2]; [1]Department of Experimental Psychology, University of Oxford, Oxford, United Kingdom, [2]Oxford Centre for Human Brain Activity, University of Oxford, Oxford, United Kingdom

Rhythmic patterns in our environment, such as music or speech, can flexibly induce temporal expectations. Such rhythmic facilitation gives rise to enhanced perceptual processing by means of temporal orienting of attention and foreperiod effects. So far, the benefits of temporal expectations have only been described within task designs in which individuals perform discrete tasks on a trial-by-trial basis. The current study is designed to investigate how temporal expectations are formulated dynamically during an ongoing Continuous Performance Task (CPT) with an implemented rhythmic structure. By using this ongoing task design, we were also able to investigate whether the lack of a rhythmic structure leads the cognitive system to adjust to operate in temporal uncertainty. A new CPT variation was designed to allow the estimation of parameters derived from the Theory of Visual Attention (TVA), a mathematical model which provides a comprehensive account of attention-related processes. Participants monitored a continuous stream of arrow-shaped targets that appeared for varying durations (10-80ms) and were followed by a mask. During the interstimulus intervals, they were requested to indicate the direction of each arrow (if they had managed to identify it) and pupillometry data was recorded. The interstimulus intervals were manipulated so that targets appeared in either an isosynchronous rhythm or unpredictably within a random temporal structure. In accordance with previous reports, temporal expectations improved the visual processing speed TVA parameter. Strikingly, random temporal structures also conferred a unique benefit, yielding a lower perceptual threshold according to TVA. Therefore, while temporal predictions facilitate efficient visual processing, increasing the temporal uncertainty promotes higher perceptual sensitivity. The behavioural observations were correlated with dynamic shifts in pupil dilation, showing phasic increases before predictable onsets and overall expansion in temporal uncertainty. The results indicate a dynamic adaptation of attention in accordance with the temporal structure to maximize performance.

53.465 **Microsaccades reveal the temporal dynamics of template and response preparation during visual search.** Katya Olmos Solis[1](kos220@vu.nl), Anouk M van Loon[1,2], Sander A Los[1,2], Christian N.L. Olivers[1,2]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, The Netherlands, [2]Institute of Brain and Behavior Amsterdam, Vrije Universiteit Amsterdam, The Netherlands

Theories of visual search assume that selection is driven by an active template representation of the target object. Earlier studies suggest that template activation occurs prior to search, before the matching input appears in view, but the temporal dynamics of such pre-activation remain unclear. We demonstrate that microsaccades reflect the preparation process for visual search, in terms of both template-specific activation of target features (what to search for) and general preparation to respond (when to start searching). Participants memorized a target color (i.e. the template) for an upcoming search task. During the delay, we presented an

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irrelevant Rapid Serial Visual Presentation (RSVP) of lateralized colored disks and manipulated the length of the delay in blocks of long (4650 ms) and short (2790 ms) trials. Crucially, at different time points into the delay, the template color was inserted in the RSVP, allowing us to measure specific attentional biases towards this template location as a function of time. Results revealed a general suppression of saccade production in preparation to search: the closer in time to the task, the fewer saccades the participants made. Strikingly, this suppression was stronger when a template-matching disk was present. Moreover, in the time points where a template-matching disk was presented, relatively more and larger saccades went to the matching disk than to an irrelevant color, an effect that also became stronger near the end of the delay. We conclude that observers adapt search template activation to the anticipated moment of search, and that microsaccades track the dynamics of preparing for selection in visual search tasks.

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53.466 **Voluntary temporal attention affects the rate and timing of microsaccades** Rachel Denison[1](rachel.denison@nyu.edu), Shlomit Yuval-Greenberg[2], Marisa Carrasco[1]; [1]New York University, [2]Tel Aviv University

Goal The timing of visual events is often predictable, allowing observers to voluntarily attend to relevant points in time. Voluntary temporal attention increases perceptual sensitivity, but the underlying dynamic processes are unclear. Microsaccades, or small fixational eye movements, are thought to contribute to the active sampling of visual information and can be modulated by expectations. Here we asked whether voluntary temporal attention affects the rate and timing of microsaccades. Methods In different experiments two or three oriented grating targets (T1, T2, T3) were presented sequentially, 250 ms apart, in the same spatial location on each trial. A precue tone 1000 ms before T1 indicated which target was likely to be probed. A postcue tone 500 ms after T2 or T3 indicated which target's orientation to report. In valid trials (60%), the precue and postcue matched, in invalid trials (20%), they did not match, and in neutral trials (20%), the precue was uninformative as the targets were equally likely to be probed. Trials with blinks or large saccades were rejected online and repeated later in the session. Microsaccades were identified offline. Results Temporal cueing improved orientation judgment accuracy. For all cueing conditions, microsaccade rate decreased approximately linearly during the 500 ms before T1 and remained near zero until rebounding 300-500 ms after T1. Microsaccades were fully inhibited earlier and rebounded earlier given a T1 precue compared to a neutral, uninformative precue. In addition, the microsaccade rate was lower in the T1 compared to the neutral cueing condition during the 500 ms before T1. Conclusions Voluntary temporal attention changes microsaccade rate and timing, reflecting a cognitive influence on the rate and precise timing of fixational eye movements, even when no target stimulus is physically present.

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53.467 **Get more out of your data: Breaking down response time to improve its usefulness** Michelle R Kramer[1](kramerm@gwu.edu), Dwight J Kravitz[1], Stephen R Mitroff[1]; [1]Department of Psychology, The George Washington University

Behavioral science has greatly benefited from a simple but powerful dependent measure—response time (RT). This measure provides a window into cognitive processes, but it is not as simple as commonly assumed—meaningful information can be gained by breaking RT into subcomponents. Prior research has investigated the positive skew of RT distributions, leading to several models including Ex-Gaussian (Hohle, 1965) and Ex-Wald (Schwarz, 2001). A common theme of the models is that RT is comprised of multiple underlying components with different distributions, mainly a motor initiation and decision process. Here, we explored whether the decision process is the more meaningful cognitive measure that can be better leveraged as a dependent variable when distinguished from the motor process. Participants completed an object-sorting task (from the mobile application Airport Scanner; Kedlin Co., www.airportscannergame.com) in which they classified a series of objects by first touching and then swiping the objects to the top or bottom of their mobile device touch screen. The "touch and swipe" response method allowed RT to be separated into two subcomponents: 1) the time from stimulus appearance to initial contact with the screen—motor initiation, and 2) the time from initial contact to ultimate classification of the item—decision process. These two components of the overall RT only weakly correlated with each other across participants, supporting their status as unique subcomponents. Further, they were differentially related to trial accuracy and individual difference measures, and had different learning curves. Overall, the decision component appears to be the more interesting RT subcomponent, and it has strong relationships to cognitive effects—sometimes much stronger than overall RT. While overall RT is useful, these analyses suggest we could be missing, or occluding, additional effects, which can be recovered by separating RT into subcomponents to distinguish decision from motor initiation processes.

Acknowledgement: Army Research Office

Perception and Action: Walking, navigating, driving

Tuesday, May 22, 8:30 am - 12:30 pm

Poster Session, Pavilion

53.468 **Testing models of speed control in 1D pedestrian following** Jiuyang Bai[1](jiuyang_bai@brown.edu), William H. Warren[1]; [1]Department of Cognitive, Linguistic and Psychological Science, Brown University

Global patterns of crowd behavior are believed to result from local interactions between pedestrians. Many studies have investigated the local rules of interaction, but how a pedestrian controls walking speed when following a leader remains in dispute. The present study experimentally tested six speed control models from the pedestrian and car following literature. These dynamical models control the follower's acceleration based on the leader's distance (distance model), speed difference (speed model), a combination of speed and distance (speed-based distance model, ratio model, linear model), or visual angle (optical expansion model). Previously, Rio, Rhea, & Warren (2014) reported evidence consistent with several models; here we dissociate them by testing a wider range of initial distance conditions. A participant (N=10) walked in a virtual environment while wearing an Oculus CV1 HMD, and head position was recorded (sampled at 60 Hz). They were asked to follow a virtual moving target pole for 12m, which changed speed after 2-3s. The target's initial distance (1, 4, 8m), initial speed (0.8, 1.2 m/s), and change in speed (-0.3, 0, +0.3 m/s) were randomly varied on each trial. All variables had significant effects on the participant's final speed and distance ($p < .0001$). Each model was fit to the participants' time series of speed using a Monte Carlo cross-validation procedure with 100 repetitions and a 75%/25% training/test split, then parameters were fixed. The linear model (four free parameters) had the highest correlation with follower's speed, but the optical expansion model (one free parameter) had the lowest RMS error in speed in all conditions; the other models exhibited an increase in RMS error at longer distances. The results imply that pedestrians directly control their walking speed by accelerating to cancel the optical expansion/contraction of the leader, rather than relying on the leader's distal speed or distance.

Acknowledgement: Supported by NSF BCS-1431406

53.469 **Metric vs. Topological Models of Collective Motion in Human Crowds** Trenton D Wirth[1](trenton_wirth@brown.edu), Gregory C Dachner[1], William H Warren[1]; [1]Brown University

Collective motion in human crowds is thought to emerge from local interactions between individual pedestrians (Warren, CDPS, in press). A key problem in modeling collective motion is understanding how a pedestrian is influenced by multiple neighbors. Different models have been suggested for modeling the collective motion of animals. A topological model, in which an individual is influenced by a fixed number of neighbors, independent of distance, has been found to describe starling flocks (Ballerini et al., 2008). A metric model, in which an individual is influenced by all neighbors within a zone of fixed radius, has been reported in chimney swifts (Evangelista et al., 2016). Similarly, we have experimentally derived a "soft" metric model, in which neighbor influence decreases exponentially with metric distance, that best describes human crowd behavior (Warren & Dachner, VSS 2017). To test these models we previously manipulated the density of a virtual crowd, and perturbed the

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walking direction of a subset of neighbors (Warren & Rio, 2014; Wirth & Warren, 2016). Both studies found that the participant's turning response depended on crowd density, contrary to a topological model. In the first study, the perturbed neighbors were in random positions, and the response was stronger in the high density condition than the low density condition. The second study was constructed to elicit a stronger response in the low density condition, by always perturbing the nearest neighbors at fixed distances. Here we use the soft metric model to predict both sets of results. The model closely reproduces the observed effects of density, including the reversal of the high and low density conditions. The results rule out a topological neighborhood in human crowds, and provide support for the soft metric neighborhood model.

Acknowledgement: NSF BCS-1431406

53.470 **Comparing Simple-radius and Doughnut Models of Collective Crowd Motion** William Warren[1](Bill_Warren@brown.edu), Gregory Dachner[1]; [1]Department of Cognitive, Linguistic, and Psychological Sciences, Brown University

In previous research, we developed an experiment-driven model of collective motion in human crowds (Warren, CDPS, in press). The behavioral dynamics model combines a local 'alignment' interaction, in which a pedestrian matches the speed and heading of a neighbor (Rio, Rhea, & Warren, 2014) with a neighborhood model, which computes a weighted average of multiple neighbors, with weights that decay exponentially with distance out to 4m (Warren & Dachner, VSS 2017; cf. Cuker & Smale, 2007). In addition, we found that the weight decreases more gradually with the distance to the nearest neighbor out to 11m (Wirth, Warren (& Richmond), VSS 2016), forming a larger doughnut-shaped neighborhood. Here we explore the model in multi-agent simulations, to determine the conditions under which it generates collective motion and to compare the simple-radius and doughnut neighborhoods. 30 interacting agents, with human parameters, were simulated on each 20s run, with synchronous updating. Their initial positions on a 5x6 grid were jittered, and initial conditions were parametrically varied: interpersonal distance (IPD=1-10m), heading range (±10˚ to ±90˚), and speed range (±0.1 to ±0.9 m/s). There were 20 runs per condition, and the SD of final heading and speed were measured. The model converges to coherent motion over a wide range of initial headings and speeds, but less so as IPD increases. In addition, the number k of clusters of agents tends to increase with variation in initial conditions. Notably, the doughnut model converges over a larger range of conditions than the simple-radius model, providing a robust alternative to a 'topological' neighborhood that is not distance-dependent (Wirth & Warren, VSS 2018). We are currently comparing this physical model with a vision-based model driven by optical variables (Dachner & Warren, VSS 2017, 2018). Thus, the doughnut model generates collective motion that is robust to variation in initial conditions.

Acknowledgement: NSF BCS-1431406

53.471 **A vision-based model of following in a human crowd** Gregory C Dachner[1](gregory_dachner@brown.edu), William H Warren[2]; [1]Brown University, [2]Brown University

Collective behavior in human crowds emerges from the local interactions between individual pedestrians. Previously, we found that people generate collective motion by 'following' their neighbors, specifically, by aligning their velocity vector with a weighted average of physical velocities in a neighborhood (Warren & Dachner, VSS 2017; Warren, CDPS, in press). Here we present a vision-based model of this alignment behavior. Dachner & Warren (VSS 2016, 2017) showed that a participant follows a single leader by nulling the leader's optical expansion and angular velocity, depending upon the leader's visual direction. They simulated the data using a dynamical model that takes only these optical variables as input. We now use this vision-based model to simulate human data on following a virtual crowd (from Rio et al., 2014). A participant (N=10) was instructed to 'walk with a crowd' of twelve virtual neighbors for 10m while wearing an Oculus DK1 HMD. A subset of neighbors (0, 3, 6, 9, or 12) changed speed (+/- 0.3 m/s) or direction (+/- 10 degrees) on each trial, and the participant's trajectory was recorded at 60 Hz. The data were simulated using the vision-based model and compared with results from our earlier physical model, with fixed parameters. The RMS Error of heading between model and participant was significantly lower for the vision-based model (4.1 degrees) than the physical model (4.9 degrees), t(9) = 3.35, p < .01. These results suggest that optical variables govern following in a crowd, which can explain previously observed effects of neighbor distance (Rio et al., 2014) as a consequence of the laws of perspective. Most crowd models are based on physical variables, not visual information. We conclude that the vision-based model better simulates following in a crowd, and it is this visual coupling between pedestrians that generates collective motion.

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53.472 **Optical Variables Influencing Barrier Avoidance** Brittany A. Baxter[1](brittany_baxter@brown.edu), William H. Warren[2]; [1]Brown University, [2]Brown University

How do people circumvent a barrier en route to a goal? Baxter & Warren (2017) found that participants preferred a waypoint at the end of the barrier that was a closer distance (d) to their starting point and/or a smaller deviation angle (β) from their initial heading. Here we dissociate the deviation angle (β), which would reduce turning, from the visual angle (α) between the waypoint and the goal, which would yield a shorter path. A participant (N=10) walked in a virtual environment while wearing an Oculus HMD. On each trial, they started walking towards an orientation pole, setting their initial heading. After progressing 2m the disappearance of the orientation pole and simultanious appearance of a 3m barrier in front of a goal pole was triggered. In half the trials the orientation and goal pole positions were the same, and in the other half they were positioned at the opposite ends of the barrier, putting β and α in conflict). The barrier's orientation (±45º, ±75º from sagittal) and lateral offset (± 0.4m from start-orientation line) were varied. The left/right response was analyzed using a mixed-effects logistic regression model. All fixed-effects variables (d, β, and α) significantly predict whether the average participant avoids to the right (p< .001). When the right barrier end is 1m closer, the odds of passing to the right are 3.41 higher than the left; when β and/or α is 1º smaller to the right, the odds are also higher (1.15, 1.38; respectively). Scaled to standardized units, however, α has a greater odds ratio (28.44) than β or d (6.01 and 4.38). The results indicate that the distance, heading deviation, and goal angle all influence waypoint selection in barrier avoidance. The goal angle, which often coincides with the heading deviation, is the strongest predictor, possibly because it indicates a shorter path to the goal.

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53.473 **Individual Differences in Self-recognition from Body Movements** Akila Kadambi[1](akadambi@ucla.edu), Hongjing Lu[1,2]; [1]Department of Psychology, University of California Los Angeles, [2]Department of Statistics, University of California Los Angeles

Since we rarely view our own body movements in our daily lives, understanding the recognition of self-body movements can shed light on the core of self-awareness and on the representation of actions. Previous research has revealed that people can achieve above-chance level performance in identifying themselves from impoverished point-light actions. However, little work has investigated possible individual differences in the ability to accomplish self-recognition with actions, and how such differences may relate to other abilities and traits (e.g., autistic traits, schizophrenic traits, and motor imagery ability).The present study first recorded 9 simple and 9 complex actions performed by individual participants, who also subsequently observed 9 videos displayed on the screen, and imitated these actions. After a delay period of 35-40 days, participants were asked to identify their own-body movements presented as point-light displays among 3 other actors who performed the same actions. Participants were able to reliably recognize themselves solely based on kinematics in point-light displays. However, self-recognition accuracy varied according to the complexity of performed actions, with more accurate self-recognition for complex than simple actions. Success in self-recognition with simple actions showed a significant relation with autistic traits (poorer self-recognition accuracy for those more autistic traits), with schizophrenic traits (participants with roughly median degree of schizophrenia traits performed better than participants at the extremes), and with motor imagery traits (increased self-recognition accuracy with greater internal motor imagery). We also found that participants did not recognize actions based only on visual experience, but could identify their self-generated actions that required motor experience, underscoring the importance of motor experience to the representation of own-body

movements. Overall, the present study showed that the perceptual representation of self-generated actions is affected by the degree of autistic and schizophrenic traits, as well as by the interplay of visual and motor experience.

Acknowledgement: National Sciences Foundation (NSF)

53.474 **Learning to Integrate Egocentric and Allocentric Information using a Goal-directed Reward Signal** Arthur W Juliani[1](a-juliani@uoregon.edu), Margaret E Sereno[1]; [1]University of Oregon

Recent work in Deep Reinforcement Learning has demonstrated the ability for a parameterized model to learn to solve complex tasks from a sparse reward signal. A consequence of this learning is often a meaningful latent representation of the observational data. The composite nature of neural networks opens the possibility of learning joint representations between not just one, but multiple sensory streams of information. In this work, we train a neural network to learn a joint spatial representation that combines separate egocentric and allocentric visual streams, corresponding to a 3D first-person view and 2D map view. We used a simple 3D environment with a goal-driven navigation task. In order to fully explore the relationship between the two information streams, we employed multiple experimental conditions where each stream contained variable amounts of relevant spatial information, specified as follows. The egocentric perspective could contain one of three levels of information ("None", "Partial" - the goal is invisible, or "Full" - the goal is visible). Likewise, the allocentric perspective contained one of three levels of information: ("None", "Partial" - the goal is present, but self-location is not indicated, or "Full" both the goal position and self-location are indicated). We demonstrate the novel result that a goal-driven reward signal can be used to guide the learning of a joint representation between allocentric and egocentric visual streams. Additionally, in the condition involving imperfect information from both streams ("Partial" - "Partial") the network was able to learn to successfully combine the streams in a representation that contains near-perfect global self-location and orientation information, even when this information was not explicitly available in either visual stream, and allowed for near-optimal performance. We compare these learned representations to those prototypical of the mammalian "cognitive map," as well as compare behavior results between our trained models and human participants.

Acknowledgement: This work was supported by a National Institute on Drug Abuse Grant (No. R21DA024293)

53.475 **Models of navigation and pointing in non-metric environments** Alexander A. Muryy[1](a.muryy@reading.ac.uk), Andrew Glennerster[1]; [1]School of Psychology & Clinical Language Sciences, University of Reading, UK

Different models of spatial representation have been suggested to explain the behaviour of people as they navigate and remember the location of objects: full metric reconstruction, topological representation and labelled graphs (Warren, 2016). Some tasks require a topological representation, while others require a metric representation and different representations might be used for different tasks. In our experiment, human participants (n=8) were asked to perform two spatial tasks in a virtual labyrinth: navigational and pointing. The navigational task was to collect 4 coloured targets in a specified order and then, from the last location, to point to all other targets, which were not currently visible. There were 5 repeats with the same target order ('learning' phase) and three repeats with a different target order ('test phase'). We tested participants both in physically-realisable configurations ('metric') and impossible, non-metric configurations with 'wormholes' that increased the length and number of turns between pairs of locations in the maze but did not alter the topological structure. The participants navigated efficiently even in the most difficult non-metric condition. We predicted participants' routes in the test phase using data on successful routes from the learning phase. For long paths in the wormhole conditions, this model predicted participants' routes significantly better than assuming they followed the shortest metric route or the shortest topological route. This is what one would expect if they learn the topological structure of the maze gradually. For the pointing results, we computed the most likely metric configuration of the targets that would be consistent with the participant's pointing directions. In the wormhole conditions (but not in the metric condition), this provides a better explanation of pointing responses than ground truth (using Akaike information criterion) and suggests ways in which participants might create a distorted metric representation of the maze containing wormholes.

Acknowledgement: EPSRC EP/N019423/1

53.476 **Steering a car to intercept a moving target: Can people learn a better interception solution?** Huaiyong Zhao[1](huaiyongzhao@126.com), Dominik Straub[1], Constantin A. Rothkopf[1]; [1]Institute of Psychology, Technical University Darmstadt

As people steer a car to intercept a moving target, we have shown that they keep the target in a roughly constant direction with reference to the car's heading direction, consistent with the constant target-heading strategy (Zhao, Straub, & Rothkopf, 2017). This pattern of steering usually results in a curved interception path, which is suboptimal due to its longer traveled distance compared with a straight interception path. In the current study, we examined whether participants can learn a better interception solution. Participants (N=8) steered a car (moving at a fixed speed of 7 m/s) to intercept a moving target in virtual environments. In the learning sessions, they intercepted the target in four target conditions, two target movement directions (horizontally left/right) by two target speeds (4.5 or 5.5 m/s). They learned in an environment consisting of a textured ground plane, a blue sky with clouds, and surrounding background image, which provided rich visual information about optic flow and allocentric reference frames. After five learning sessions on different days, participants were tested in two test sessions on the same day with 20 target conditions in each session, four target movement directions (horizontally left/right and approaching from the left/right) by five target speeds (4, 4.5, 5, 5.5, or 6 m/s). In the first test session, participants intercepted the target in the same environment as in the learning sessions; in the second test session, they intercepted the target in an environment consisting of only a ground plane of solid green and a grey sky, which provided no visual information about optic flow or allocentric reference frames. The results show that participants learned to intercept the moving target more efficiently by steering a straighter interception path. Moreover, the learned steering pattern can be generalized to the new target motion and the new environment.

53.477 **The effects of age and following a lead car on scanning for and detection of motorcycle hazards at intersections** Steven W Savage[1](steven_savage@meei.harvard.edu), Lily Zhang[1], Garrett S Swan[1], Dora Pepo[2], Alex R Bowers[1]; [1]Schepens Eye Research Institute, MEEI, Harvard Medical School, [2]New England College of Optometry (NECO)

Older drivers are more frequently involved in collisions at intersections than middle aged drivers. Police reports suggest that over 50% of such collision events were in some way related to older drivers not scanning their visual surroundings sufficiently well. Within the simulated driving literature there is conflicting evidence concerning older drivers' scanning behavior at intersections. Some studies reported that older and younger drivers made similar numbers of head and eye scans, whereas others have demonstrated that older drivers made fewer scans. Furthermore studies have employed different methods with which to guide their participants through the simulated world, which in turn may have affected participants scanning and therefore their detection performance. The current study investigated the effects of age and guidance type on drivers' scanning for and detection of motorcycle hazards at intersections and examined the relationship between scanning behavior and detection performance. We recruited 19 younger (20-40 years) and 16 older (65+ years) drivers, who completed two drives through 43 intersections (16 with motorcycle hazards) in our driving simulator, once following a lead car and once following GPS instructions. Rates of failing to detect a motorcycle were low (about 10%) and did not differ between the two age groups. We found that younger subjects made larger glances, had faster reaction times and shorter search times, but their detections were more frequently unsafe because they drove more quickly. Preliminary analyses suggest that both older and younger subjects made fewer glances in the lead car than the GPS drive. Smaller glances were related to detection failures in both age groups. However, although older drivers made smaller glances on average than younger drivers, they did not have higher miss rates because they were later in making their detections when the motorcycle was at a smaller eccentricity, within the range of their glances.

Acknowledgement: NIH RO1- EY025677 T35-EY007149 & S10-RR028122

53.478 **The effects of simulated acuity and contrast sensitivity impairments on detection of pedestrian hazards** Garrett Swan[1](gsp.swan@gmail.com), Maha Shahin[2], Jacqueline Albert[3], Joseph Herrmann[4], Alex Bowers[1]; [1]Schepens Eye Research Institute, MEEI, Harvard Medical School, [2]Ophthalmology, Mansoura University, [3]Southern California College of Optometry, Marshall B. Ketchum University, [4]School of Medicine, Texas Tech University Health Sciences Center

Driving is a highly visual task, yet the vision requirements for driving licensure vary widely. All states have a threshold for visual acuity (e.g. most use 20/40 for an unrestricted license, but visual acuity can be as low as 20/200 for a license that restricts driving to daytime or the local area only). Surprisingly, however, contrast sensitivity is rarely considered, despite evidence that it may be a better predictor of crash risk than visual acuity. In two experiments ($n = 30$), we investigated how simulated reductions in visual acuity and contrast sensitivity selectively affect the detection of pedestrians in a driving simulator. Young normally-sighted participants (20 – 40 years) wore goggles simulating different levels of visual acuity and contrast sensitivity loss (within a range that would meet licensing criteria) and detected pedestrians in a highway setting by pressing the horn as soon as they saw a pedestrian. The proportion of pedestrians detected was not different between the conditions. Reducing contrast sensitivity significantly increased reaction times ($p < 0.005$), while visual acuity only marginally increased reaction time ($p < 0.1$). When calculating the safety of the detection, which takes into account the speed of the car and pedestrian at the time of the horn press, only the combined reductions in visual acuity and contrast sensitivity significantly affected safety ($p < 0.005$). These results suggest that an individual's contrast sensitivity should be considered when determining visual fitness to drive, especially in the early stages of ocular disease, such as cataract, where contrast sensitivity may be impaired while high contrast acuity is still relatively normal. Contrast sensitivity may be the more relevant measure of visual function because distinguishing the hazard from the background is more important than determining what that hazard is.

Acknowledgement: NIH grants R01-EY025677 and T35-EY007149

53.479 **Optimal integration of heading specified by optic flow and target egocentric direction** Wei Sun[1](sunguwei@gmail.com), Zhenyu Zhu[2], Jing Chen[2], Guangtao Zhai[1], Michael Landy[3], Li Li[2]; [1]Department of Electronic Engineering, Shanghai Jiao Tong University, PRC, [2]NYU-ECNU Institute of Brain and Cognitive Science, New York University Shanghai, PRC, [3]Department of Psychology and Center for Neural Science, New York University, New York, US

Background. Previous research suggests that heading specified by optic flow and target egocentric direction are used for the control of walking toward a goal. We examined whether these two cues are optimally combined in this process. Methods. In the walking task, participants ($n=12$) wore a head-mounted display (Oculus DK2, FOV: 100°) and walked toward a line target (width: 0.5°, retinal size did not increase with approach) placed at 8 m in (1) an empty virtual environment that provided only target egocentric direction or (2) with a textured ground and ceiling that also provided dense optic flow. Participants' heading in the virtual environment was displaced ±15° from their physical walking direction (i.e., straight ahead). In the perceptual task, participants passively viewed displays of the textured ground and ceiling environment with heading specified by optic flow displaced ±15° away from straight ahead. They judged perceived heading with a mouse-controlled probe at the end of each 1 s simulated self-motion display. Results. The heading error was 15° throughout the course of walking toward the target with the empty environment. With the textured environment, heading error dropped quickly and was reduced to 7° on average by the end of each trial. For the perceptual task, with a heading offset of 15°, perceived heading from optic flow had a center bias of 3.7°. Mean heading error and SD observed in the perceptual task (heading cue) and the walking task with the empty environment (target egocentric direction cue) successfully predicted heading error in the walking task with the textured environment (cue conflict) assuming optimal cue integration. This supports the claim that heading specified by optic flow and target egocentric direction cues are optimally combined for goal-oriented locomotion control.

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Perception and Action: Decisions

Tuesday, May 22, 2:30 - 4:15 pm, Talk Room 1

Moderator: Mike Landy

54.11, 2:30 pm **Modeling contextual flexibility in visual communication** Judith E Fan[1](jefan@stanford.edu), Robert X.D. Hawkins[1], Mike Wu[2], Noah D Goodman[1,2]; [1]Department of Psychology, Stanford University, [2]Department of Computer Science, Stanford University

Visual modes of communication are ubiquitous in modern life — from maps to data plots to political cartoons. Here we investigate drawing, the most basic form of visual communication. Communicative drawing poses a core challenge for theories of how vision and social cognition interact, requiring a detailed understanding of how sensory information and social context jointly determine what information is relevant to communicate. Participants (N=192) were paired in an online environment to play a drawing-based reference game. On each trial, both participants were shown the same four objects, but in different locations. The sketcher's goal was to draw one of these objects — the target — so that the viewer could pick it out from a set of distractor objects. There were two types of trials: close, where objects belonged to the same category, and far, where objects belonged to different categories. We found that people exploited information in common ground with their partner to efficiently communicate about the target: on far trials, sketchers achieved 99.7% recognition accuracy while applying fewer strokes, using less ink, and spending less time (ps< 0.001) on their drawings than on close trials. We hypothesized that humans excel at this task by recruiting two core competencies: (1) visual abstraction, the capacity to perceive the correspondence between an object and a drawing of it; and (2) social reasoning, the ability to infer what information would help a viewer distinguish the target from distractors. We instantiated these competencies in a computational model of communicative drawing that combines a multimodal convnet visual encoder with a Bayesian model of recursive social reasoning, and found that it fit the data well and outperformed lesioned variants of the model. Together, this work provides the first unified computational theory of how perception and social cognition support contextual flexibility in real-time visual communication.

54.12, 2:45 pm **Assessing the role of rewards and priors on confidence judgments** Elon Gaffin-Cahn[1](eg.gc@nyu.edu), Shannon M Locke[1], Nadia Hosseinizaveh[1], Pascal Mamassian[2], Michael S Landy[1,3]; [1]Department of Psychology, New York University, New York, [2]Laboratoire des Systèmes Perceptifs, CNRS UMR 8248, Départment d'Études Cognitives, École Normale Supérieure, Paris, France, [3]Center for Neural Science, New York University, New York

Humans can adjust decision criteria to incorporate the probability of an event and the potential rewards or cost of the choice. Often, this adjustment is smaller than optimal, which is called conservatism. Self-assessment of the quality of these decisions is called confidence. While the probability of an event should affect criterion placement for both the decision and confidence assessment, the reward structure should only impact the former. We tested whether humans are optimal or conservative in perceptual judgments and whether they incorporate prior probabilities, potential rewards, or neither in their confidence reports. On each trial, participants performed an orientation-discrimination task (left vs. right), followed by a confidence report in their orientation judgment (high vs low). The probabilities of the two orientations and the rewards for a correct answer for each orientation varied independently across sessions. Participants received explicit instructions on the values of the priors and rewards and performed a practice block before testing. We used Signal Detection Theory to model the discrimination and confidence criteria. We modeled confidence as a region bounded by symmetric criteria centered on a hypothetical discrimination criterion that accounts for the prior and reward, the prior only, or neither. The hypothetical criterion could share conservatism with the discrimination criterion or have no conservatism. As in previous studies, participants were conservative in the orientation-discrimination task. Preliminary results show that participants correctly ignored potential reward when making the confidence judgment. Importantly, confidence judgments were not affected by conservatism. That is, the hypothetical criterion for the orientation-discrimination task is not shifted by conservatism. Thus, conservatism is introduced to decision making during perceptual decisions but not during evaluations of those decisions. This has implications for understanding the basis of different components and processes in human decision making.

Acknowledgement: NSF GRFP DGE 1342536, T90DA043219, NIH EY08266, NSF BCS-1430262

54.13, 3:00 pm **Confidence predicts variability but not biases in perceptual decisions** andrea bertana[1](andrea.bertana1@gmail.com), Ruben S. van Bergen[1], Sam Ling[2], Janneke F.M. Jehee[1]; [1]Donders Institute for Brain, Cognition and Behavior & Radboud University, [2]Boston University

Although confidence is commonly believed to be an essential element in decision making, it remains unclear what gives rise to our sense of confidence. Recent probabilistic theories propose that one's confidence is computed, in part, from the degree of uncertainty in sensory information. If confidence indeed reflects the imprecision of perceptual evidence, then greater levels of confidence should predict 1) less variable behavior, and 2) smaller biases in perception, as both behavioral variability and perceptual biases are linked to uncertainty. Here, we test these predictions using a combination of psychophysics and computational modeling. Participants viewed a stimulus that consisted of an array of 36 gabor patches, and reported both the mean orientation of the array, and their confidence in this estimate. Patches were variable in orientation (drawn from a Gaussian distribution), and five noise levels were used to parametrically manipulate uncertainty (s.d. = 0.5, 2, 4, 8 and 16). Corroborating the first prediction, we found that for a given stimulus orientation, confidence reliably predicted behavioral variability. Specifically, orientation estimates were more precise with higher confidence, both across and within levels of orientation noise. Surprisingly, however, the results deviated from our predictions when comparing between stimulus orientations: although orientation judgments were more accurate for cardinal orientations (a phenomenon known as the oblique effect), confidence was higher for oblique orientations. In addition, we observed no reliable link between confidence and the magnitude of behavioral biases. Rather than being consistent with Bayesian decision theory, we argue that these results are better explained by the ability of observers to perceive the degree of orientation noise in the stimulus – a heuristic to confidence.

Acknowledgement: This work was supported by ERC Starting grant 677601 to J.J.

54.14, 3:15 pm **The influence of low-level stimulus characteristics on metacognitive efficiency** Dobromir Rahnev[1](drahnev@gmail.com), Ji Won Bang[1,2], Medha Shekhar[1]; [1]School of Psychology, Georgia Institute of Technology, [2]Department of Ophthalmology, School of Medicine, New York University,

Metacognition is the ability to employ confidence ratings in order to predict the accuracy of one's decisions. Despite years of research, it is still unclear how visual metacognitive efficiency can be manipulated. In particular, it is typically assumed that the low-level stimulus characteristics have no impact on the metacognitive efficiency. However, we show that a hierarchical model of confidence generation makes a counterintuitive prediction: Higher sensory noise should increase metacognitive efficiency. The reason is that sensory noise has a large negative influence on the decision (where it is the only corrupting influence) but a smaller negative influence on the confidence judgment (where it is one of two corrupting influences; the other one being metacognitive noise). To test this prediction, we used a perceptual learning paradigm to decrease the amount of sensory noise. In Experiment 1, seven days of training led to a significant decrease in noise as well as a corresponding decrease in metacognitive efficiency. Experiment 2 showed the same effect in a brief 97-trial learning for each of two different tasks. Finally, in Experiment 3, we combined

increasingly dissimilar stimulus contrasts to create conditions with higher sensory noise and observed a corresponding increase in metacognitive efficiency. Our findings demonstrate the existence of a robust positive relationship between sensory noise and metacognitive efficiency. These results could not be captured by a standard model in which decision and confidence judgments are made based on the same underlying information. Thus, our study provides a novel way to directly manipulate metacognitive efficiency via the low-level stimulus characteristics and suggests the existence of metacognitive noise that corrupts confidence but not the perceptual decision.

54.15, 3:30 pm **Laws of concatenated perception: Vision goes for novelty, Decisions for perseverance** David Pascucci[1,2](david.pascucci@unifr.ch), Giovanni Mancuso[2], Elisa Santandrea[1], Chiara Della Libera[1,3], Gijs Plomp[2], Leonardo Chelazzi[1,3]; [1]Department of Neuroscience, Biomedicine and Movement Sciences, University of Verona, Verona, Italy, [2]Department of Psychology, University of Fribourg, Fribourg, Switzerland, [3]National Institute of Neuroscience, Verona, Italy

Every instant of perception depends on a cascade of brain processes calibrated to the history of sensory and decisional events. In the present work, we show that human visual perception is constantly shaped by two contrasting forces, exerted by sensory adaptation and past decisions. Using the method of adjustment, in a series of experiments we measured the ability of human participants to reproduce the orientation of consecutive Gabor stimuli. Multi-level non-linear models and cross-validation techniques were adopted to investigate the impact of previous stimuli and responses on current adjustment errors. Our results revealed that each perceptual report is permeated by opposite biases from a hierarchy of serially dependent processes: low-level adaptation repels perception away from previous stimuli; high-level, decisional traces attract perceptual reports toward previous responses. Contrary to recent claims, we demonstrated that positive serial dependence does not result from continuity fields operating at the level of early visual processing, but arises from the inertia of decisional templates. This finding is consistent with a Two-process model of serial dependence in which the persistence of read-out weights in a decision unit compensates for sensory adaptation, leading to attractive biases in sequential responses. We propose the first unified account of serial dependence in which functionally distinct mechanisms, operating at different stages, promote the differentiation and integration of visual information over time.

54.16, 3:45 pm **Body positioning in realistic ball interception accounts for visuomotor idiosyncrasies** Imogen Large[1](i.large@ucl.ac.uk), Jeroen Smeets[2], Eli Brenner[2], Tessa Dekker[1]; [1]UCL Institute of Ophthalmology, [2]Vrije Universiteit Amsterdam

The visuomotor system is highly optimised for visually guided reaching in simplified tasks capturing real-world problems (Battaglia & Schrater, 2007; Dean, Wu, & Maloney, 2007; Trommerhauser et al, 2005; Faisal & Wolpert, 2009). However, in typical whole-body movements, task-relevant visual cues and motoric degrees of freedom increase dramatically. Can our system still account for these complexities, or does visuomotor efficiency break down under more realistic circumstances? To test this, we asked 15 participants to 'pop' water balloons with a hand-held laser in virtual reality, as they fell from two chutes to their left and right. Participants could freely move between chutes to hit as many balloons as possible. Probability of balloon interception at a chute increased when moving closer to that chute. However, balloon values varied across the two chutes, so the more valuable chute would yield more points at same viewing distance (value conditions: 1:1, 1:2, 1:3 points). As such, participants had to stand somewhere that optimally traded-off between balloon value and their own interception probability. Prior to the main task, participants were asked to intercept balloons whilst standing in fixed locations across the game area. This allowed us to interpolate how hit probabilities for each chute varied by location for each individual. Based on these measures we computed where each subject should stand to maximise their score under different balloon value conditions (ideal observer prediction). Participant behaviour was close to ideal in all conditions, with a slight tendency to stay too close to the less valuable chute for score maximisation. Interestingly, even in the 1:1 condition where chutes had equal value, participants positioned themselves optimally to account for idiosyncrasies in their own interception performance. Thus, when positioning the body in action, the visuomotor system optimally accounts for idiosyncratic biases in visuomotor execution and cost-factors in the environment.

Acknowledgement: ESRC

54.17, 4:00 pm **Expectations about low-level visual features influence late stages of cortical information processing** Nuttida Rungratsameetaweeman[1](nrungrat@ucsd.edu), Sirawaj Itthipuripat[1,2,3], Annalisa Salazar[4], John T. Serences[1,4,5]; [1]Neurosciences Graduate Program, University of California, San Diego, La Jolla, California, 92093-0109, USA., [2]Learning Institute, King Mongkut's University of Technology Thonburi, Bangkok, Thailand, 10140, [3]Department of Psychology, Vanderbilt University, Nashville, Tennessee, 37235, USA, [4]Department of Psychology, University of California, San Diego, La Jolla, California, 92093-0109, USA., [5]Kavli Institute for Brain and Mind, University of California, San Diego, La Jolla, California, 92093-0109, USA.

Two factors play an important role in shaping perception: the allocation of selective attention to behaviorally relevant stimulus features, and prior expectations about regularities in the sensory environment. Traditionally, attention is thought to modulate early sensory processing whereas expectation is thought to only affect decision making by biasing choices. However, recent results suggest that expectation can also enhance sensory encoding and increase the rate of evidence accumulation during decision making. To test these accounts, we recorded electroencephalography (EEG) data from human subjects performing a perceptual decision-making task where expectations about stimulus features (i.e., orientation and color) and motor responses were manipulated independently. We also directly manipulated the amount of available sensory evidence to validate a set of neural markers that index sensory processing and evidence accumulation (the early visual negative potential, or VN, and the centro-parietal positive potential, or CPP, respectively). While increasing the amount of sensory evidence enhanced VN amplitude and the slope of the CPP, expectations about sensory features and motor responses did not. On the other hand, violating expectations significantly impacted posterior alpha and frontal theta oscillations, signals thought to track overall processing time and cognitive conflict. Taken together, these data argue against recent theoretical frameworks and suggest that expectations about sensory and motor regularities have little impact on early visual processing and evidence accumulation. Instead, expectations influence decisions primarily by impacting cognitive control processes.

Acknowledgement: NEI R01EY025872 and James S. McDonnell Foundation award

Perceptual Organization

Tuesday, May 22, 2:30 - 4:15 pm, Talk Room 2

Moderator: Elisha Merriam

54.21, 2:30 pm **Stimulus vignetting and orientation selectivity in human visual cortex** Zvi N Roth[1](zviroth@gmail.com), David J Heeger[2], Elisha P Merriam[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, NIH, [2]Department of Psychology and Center for Neural Science, NYU

Purpose: Multivariate analyses are widely employed in human fMRI studies. But there is considerable controversy over what decoding analyses reveal about underlying neural architecture. We previously demonstrated that a coarse-scale bias for radial orientations in human primary visual cortex (V1) is both necessary and sufficient for orientation decoding. It has been hypothesized that the radial bias is related to the edge of the stimulus aperture, rather than a neural preference for radial orientation. We tested this possibility by measuring fMRI activity to oriented gratings while systematically manipulating the shape of a modulator grating. Method: Stimuli consisted of a carrier grating multiplied by a modulator. The carrier was a Cartesian sinusoidal grating (0.5 cycles/deg) that filled an annulus (0.5 to 10 deg). Orientation of the stimulus cycled through sixteen evenly-spaced angles (0-180 deg) in 24 s. The modulator was a second sinusoidal grating that was constant throughout each fMRI run. On half the runs, the modulator had an angular orientation, producing a series of 'spokes' centered on the fixation cross. On

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the other half of runs, the modulator had a radial orientation, producing 'rings' emanating from fixation. The fMRI data analysis characterized the preferred carrier grating orientation for each voxel. Results: The majority of voxels in V1 exhibited robust and reliable orientation preferences to the carrier grating, confirming that fMRI responses in human V1 are selective for orientation. However, the orientation preferences of most voxels were determined by the orientation of the modulator. For the radial modulator, voxels exhibited a radial bias. For the angular modulator, voxels exhibited a tangential bias (i.e., rotated 90 deg from radial). We observed no evidence for orientation tuning that was unaffected by the orientation of the modulator grating. Conclusions: Ostensible orientation tuning in fMRI activity arises from interactions with the edge of the stimulus aperture.

Acknowledgement: ELSC Post-Doctoral Fellowship Abroad (ZNR) NIH grant R01-EY025673 (DJH) Intramural research program at NIMH (EPM)

54.22, 2:45 pm **Representation and remapping of occluded objects in the activity of V4** Rudiger von der Heydt[1,2](von.der.heydt@jhu.edu), Shude D Zhu[2]; [1]Department of Neuroscience, Johns Hopkins School of Medicine, [2]Zanvyl Krieger Mind/Brain Institute, Johns Hopkins University

How the visual brain represents perceptual objects and how it achieves stability of object representations despite eye movements and object movements is not well understood. Here we tested the hypothesis that the visual cortex uses grouping cells to combine elementary feature signals to larger entities representing objects (von der Heydt, Frontiers in Psychology 6, 1695, 2015). The activation of such a circuit we call a "proto-object". The proto-object hypothesis predicts that the system maintains the grouping cell activity and remaps it when the image of an object moves across the retina, thereby linking retinotopic feature signals to locations in external space. We studied single neuron activity in cortical areas V2 and V4 of non-human primates using a novel free-viewing paradigm in which the subject selectively fixates target objects in an array of objects. While the subject scans the array we briefly occlude some of the objects. Eye movement recordings showed that subjects did not hesitate to saccade to occluded objects and fixated them as accurately as visible objects. The neural recordings showed that in V4, but not in V2, occluded objects produced higher firing rates than occluded background. In the special case when a saccade moved the receptive field of a neuron from background to an occluded object, its firing rate increased despite the fact that the receptive field had never been visually stimulated. Interestingly, this internal activation was suppressed for the object that had been fixated before the saccade. We concluded that V4 neurons were activated by remapping of the proto-objects, except for the one corresponding to the last fixated object ("inhibition of return"). These findings are strong evidence for persisting internal representations that are being remapped with each saccade, as postulated by the proto-object hypothesis.

Acknowledgement: NIH R01EY02966, NIH R01EY027544, ONR BAA08-019

54.23, 3:00 pm **Shape scission: causal segmentation of shape** Filipp Schmidt[1](filipp.schmidt@psychol.uni-giessen.de), Flip Phillips[2], Roland W. Fleming[1]; [1]Experimental Psychology, Justus Liebig University Giessen, [2]Psychology & Neuroscience, Skidmore College

Research on shape perception usually focuses on the estimation of local surface geometry through cues like stereopsis, shading or texture. Here, we argue that observers use these shape estimates to infer other object properties such as material composition and the transformation processes that generated the observed shape from this matter. We call this separation of object shape into intrinsic and extrinsic object properties shape scission. We investigated shape scission in a series of experiments with different groups of participants responding to a set of 8 unfamiliar rendered objects, each transformed by 8 transformations (e.g., "melted", "cut", or "inflated"). Importantly, participants did never see the untransformed versions of objects. First, participants produced adjectives in a free naming task to describe what happened to the transformed objects. Second, participants classified the objects according to either (i) their original shape, or (ii) the transformation that had been applied to them. Third, participants marked those regions of the objects that were transformed away from the original shape. Finally, participants viewed objects at 5 different levels of transformation magnitude and provided perceptual ratings of deformation. We find that participants (i) are consistent in naming the transformations, (ii) can classify unfamiliar objects according to their original shape as well as the applied transformation, (iii) can identify regions of the objects that were transformed, and (iv) can to some extent perceive the magnitude of the transformation (when compared to objective mesh deformations). Thus, we can identify "objects" across transformations and "transformations" across objects, separating observed features by their causal origin (shape scission). We can use this perceptual understanding of the causal processes to make inferences about what other members of the same class might look like and about how objects have been altered by forces in their past.

Acknowledgement: This research was supported an ERC Consolidator Award (ERC-2015-CoG-682859:

54.24, 3:15 pm **Curious objects: Preattentive processing of object complexity** Zekun Sun[1](zekun@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Objects in the world frequently strike us as being complex (and informationally rich), or simple (and informationally sparse). For example, a crenulate and richly-organized leaf might look more complex than a plain stone. What is the nature of our experience of complexity — and why do we have this experience in the first place? We algorithmically generated hundreds of smoothed-edge shapes, and determined their complexity by computing the cumulative surprisal of their internal skeletal structure — essentially quantifying the amount of information in the object. Subjects then completed a visual search task in which a single complex target appeared among identical simple distractors, or a single simple target appeared among identical complex distractors. Not only was search for complex targets highly efficient (8ms/item), but it also exhibited a search asymmetry: a complex target among simple distractors was found faster than a simple target among complex distractors — suggesting that visual complexity is extracted 'preattentively'. (These results held over and above low-level properties that may correlate with complexity, including area, number of sides, spatial frequency, angular magnitudes, etc.). Next, we explored the function of complexity; why do we experience simplicity and complexity in the first place? We investigated the possibility that visual complexity is an attention-grabbing signal indicating that a stimulus contains something worth learning. Subjects who had to memorize and later recall serially presented objects recalled complex objects better than simple objects — but only when such objects appeared within a set of other objects, and not when they were presented one-at-a-time (suggesting that the effect is not driven simply by increased distinguishability of complex shapes). We suggest not only that object complexity is extracted efficiently and preattentively, but also that complexity arouses a kind of 'visual curiosity' about objects that improves subsequent learning and memory.

Acknowledgement: JHU Science of Learning Institute

54.25, 3:30 pm **A New Class of Motion Induced Illusory Contours** Barton L Anderson[1](barton.anderson@sydney.edu.au), Kairen Tan[1], Phillip J Marlow[1]; [1]University of Sydney

Illusory contours (ICs) provide some of the most compelling data demonstrating the visual system's capacity to synthesize structure that is not present in the input. One theoretical view is that ICs are generated by processes that attempt to provide the best explanation of the input, whereas others explain IC synthesis at an implementation (mechanistic) level of analysis. Here, we report a broad new class of extremely robust IC displays that appear to support implementation level models. We created displays containing thin radial lines ("spokes"). An occluding figure consisting of a 'spiky' circular disk was placed at the center of the display and rotated over the radial spokes. The contrast of the occluding figure relative to the surround, number of spokes, and the number and amplitude of the occluding spikes were parametrically varied. We observed a striking variety of extremely vivid ICs, which appeared to rotate under the physically visible occluding surface. These ICs could take on dramatically different shapes, rigidity, and perceived motion as function of the number of spikes and spokes. The perceived strength of these ICs decreased monotonically as the contrast of the occluding figure increased, but remained visible over all but the highest level of contrast. We psychophysically measured the strength and shape of the ICs. We show that the shapes and motion of the ICs can be well explained by a model of partial border ownership, and develop a model that can accurately predict the perceived shape and motion of these different ICs. Our results suggest that the ICs formed by the accretion and deletion of thin contours are difficult to reconcile with models that attempt to treat IC formation as rational perceptual inference.

Acknowledgement: ARC

54.26, 3:45 pm **Representational dynamics of perceptual mean of sequentially presented objects varies with sequence variability** Jongrok Do[1](jongrok.do@gmail.com), Kang Yong Eo[1], Oliver James[2], Sangkyu Son[1], Joonyeol Lee[2,3], Yee-Joon Kim[1]; [1]Center for Cognition and Sociality, Institute for Basic Science, [2]Center for Neuroscience Imaging Research, Institute for Basic Science, [3]Department of Biomedical Engineering, Sungkyunkwan University

Our ability to extract accurate statistical mean from a set of items delivered sequentially over time is known to be limited by the degree of inter-item variability. However, neural mechanisms underlying such parametric relationship between the error of perceptual mean and inter-item variability remain poorly understood. Here we record electroencephalography (EEG) during multi-item perceptual mean orientation judgment task, and use a forward encoding model to directly recover information about the item orientation and the mean orientation of a sequence. Thus, we investigate the full representational dynamics across every single stage of perceptual mean computation of sequentially presented items as a function of inter-item variability. Observers viewed a sequence of ten randomly oriented Gabor patches presented centrally every 600 ms, and reported the orientation of their mean by adjusting a red probe bar, preceded by a blank period. Each sequence had either small or large orientation variance. During the blank period just before the perceptual mean judgment, cross-generalization between item and mean coding reveals that mean orientation is more accurately represented when the sequence is less variable and the accuracy of this recovered mean orientation also predicts behavioral performance of perceptual mean computation on a trial-by-trial basis. We also found that neural representation of mean orientation gradually becomes more precise toward the end of a sequence with small fluctuation whereas orientation encoding of each serially delivered item was equally precise regardless of sequence fluctuation. Our results indicate that the inverse relationship between the accuracy of perceptual mean and inter-item variability originates from the stage of accumulating evidence over time rather than the stage of encoding each individual item.

Acknowledgement: This work was supported by Institute for Basic Science Grant (IBS-R001-D1).

54.27, 4:00 pm **Electrophysiological Footprints of Grouping by Synchrony** Benay Başkurt[1](baskurt.benay@gmail.com), Aaron M Clarke[1]; [1]Bilkent University, Neuroscience Department, Ankara, Turkey

The role played by neural synchrony in representing perceptual grouping relationships is still a mystery. While early studies demonstrated that synchrony seems to play a role in perceptual grouping (Engel, Konig, Kreiter, & Singer, 1991; Gray, König, Engel, & Singer, 1989), others questioned synchrony's role, suggesting that it may be epiphenomenal (Shalden & Movshon, 1999). The debate continues today with studies like Samonds, Zhou, Bernard and Bonds (2006) showing that synchrony arises along neural representations of object contours, while Roelfsema, Lamme and Spekreijse (2004) suggests that synchrony is not used in perceptual grouping. Here, find evidence in favour of the synchrony hypothesis for perceptual grouping using EEG with human observers. We presented to pairs of flickering Gabors (one synchronous and the other with varying levels of asynchrony) and asked observers to indicate which pair was more synchronous in a paradigm similar to that used by Cheadle et al. (2008). Critically we embedded the flickering Gabors in a background of static Gabors that either made the flickering Gabors appear to be parts of the same contour, or parts of separate contours. One pattern was presented to the left visual hemifield and the other to the right hemifield, thereby allowing us to separate out the phase-locked activity in the EEG recordings representing the two patterns. An examination of the Fourier transform of the activity evoked by each pattern revealed that the one-object pattern was represented with a smaller phase difference between flickering elements than for the two-object pattern, thereby providing support for the grouping by synchrony and segmentation by asynchrony hypothesis.

Motion

Tuesday, May 22, 5:15 - 7:15 pm, Talk Room 1

Moderator: John Perrone

55.11, 5:15 pm **Visual motion statistics during real-world locomotion** Karl Muller[1](karl.muller@utexas.edu), Jonathan S Matthis[1], Kathryn Bonnen[1], Lawrence K Cormack[1], Mary M Hayhoe[1]; [1]The University of Texas at Austin

The middle temporal visual area (MT/V5) has been implicated in the representation of visual motion in primates. MT neurons encode orientation and speed of visual motion, but the distribution of speed and orientation preferences of MT neurons is not uniform. In this study, we explored whether this non-uniform distribution reflects the statistics of the natural input derived from self-motion. We measured motion patterns generated in the context of locomotion in natural outdoor environments, using a Pupil Labs mobile eye tracker to record both binocular eye position and high-resolution scene video. We approximate a cyclopean retinal input by aligning each frame from the scene camera to the point of fixation, converting the scene data to a retinal reference frame. We used the Farneback optic flow estimation algorithm to measure speed and orientation of visual motion at each pixel location across the visual field at each video frame. The distribution of motion directions is strongly biased towards downward motion in the lower visual field, and the distribution of velocities peaks at about 10 deg/s. We then calculated the motion distributions at different locations across the visual field within regions matching the spatial characteristics of MT receptive fields. This analysis showed that distribution of motion in individual receptive fields is biased as a function of both eccentricity and direction (relative to the fovea). Specifically, the distribution of motion for more eccentric receptive fields has greater motion velocities, and the vector average of motion direction is pointed away from the fovea. This pattern is consistent with a pattern of continuous outward flow from the point of fixation. This analysis allows a comparison with distributions of speed and orientation preferences measured electrophysiologically to examine whether characteristics of MT cells are shaped by the natural image motion statistics.

Acknowledgement: EY05729

55.12, 5:30 pm **The computation of angular velocity and the perceived speed of a rotating line** Kyle W Killebrew[1](kyle-killabees@gmail.com), Gideon P Caplovitz[1]; [1]University of Nevada, Reno

Angular velocity is a size-invariant motion metric that describes how fast an object is rotating. The computation of angular velocity relies on the scaling of local velocity information by the distance from the center of rotation. When we see a rotating object, what contributes to it's perceived rotation speed and do we see the objects angular velocity. To probe these questions we conducted a series of psychophysical experiments to determine how fast a line appears to rotate. The case of a rotating line is intriguing because the aperture-problem constrained measurement of local velocity is veridical—namely, as the line rotates, each point along the line's contour is moving orthogonally to the contour. We used the method of constant stimuli to determine the relative perceived speed of lines of different lengths and the method of adjustment to determine the perceived speed of a line that continuously changed length as it rotated. We found that a larger line appears to rotate faster than a shorter line. However, the difference we measured was less than would be expected if the perceived speed were based on the magnitudes of local component motion signals alone, suggesting a representation of the line's angular velocity. Additionally, we found a line that continuously changes size as it rotates appears to speed up as it gets larger and slow down as it gets smaller. This speed modulation is almost perfectly accounted for by the magnitudes of the local component motion signals, suggesting the absence of an angular velocity representation. This is likely to be the case because a computation of angular velocity requires the integration of a local motion

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signal with a computed distance from the center of rotation. This latter computation may be made difficult in the case of non-rigid motion as the distance is continually changing.

Acknowledgement: NSF 1632849 NSF 1632738

55.13, 5:45 pm **Defining and discriminating perceptual systems that extract the direction of visual motion.** George Sperling[1](sperling@uci.edu), Peng Sun[1]; [1]Department of Cognitive Sciences, University of California, Irvine

Different motion systems are defined by the complexity of preprocessing of visual input prior to the motion extraction computation. Motion extraction itself seems to be functionally similar, just with different parameters, for the different systems. A common view is that humans have a fast Fourier-based motion extraction system and a more complex non-Fourier system. The input to the Fourier system (here designated as the 1st-order system) is the normalized input stimulus filtered into oriented spatial frequency bands, modeled as pairs of yoked V1 simple cells in which one member of the pair represents positive scontrasts and the other, negative contrasts. The non-Fourier motion system actually comprises two different systems: A second-order system who's input is local contrast energy--essentially the local variance (absolute value) of the input to 1st-order, and a third-order system who's input is a figure-ground map or, more accurately, a salience map. Normally, the three systems combine their outputs. Because of the great complexity of early visual processing, one cannot specify exactly which visual stimuli stimulate which motion systems; however, there are sufficient constraints that this can be determined for specially designed visual stimuli. The three systems are defined by their input computation; they are distinguished in five ways: different temporal frequency tuning functions, different central-versus-peripheral sensitivity, oppositely directed motion aftereffects at the same retinal location, selective adaptation, and best, by phase dependence/independence: Two weak sinewave stimuli of the same spatial frequency, temporal frequency, orientation, and motion direction, exhibit both phase-dependent cancellation and enhancement when they are delivered to same system, but only phase-independent enhancement when delivered to different systems. Demonstrations: Ambiguous, oppositely-directed motion stimuli that produce perception of the higher-order direction in the fovea, the lower-order direction in periphery; new barber-pole and plaid-motion illusions that are explained by relative contributions of the different systems.

55.14, 6:00 pm **Noise, multisensory integration, and previous response in perceptual disambiguation** Cesare V Parise[1,2](cesare.parise@googlemail.com), Marc O Ernst[3]; [1]Oculus Research, [2]University of Bielefeld, [3]University of Ulm

Sensory information about the state of the world is generally ambiguous. Understanding how the nervous system resolves such ambiguities to infer the actual state of the world is a central quest for sensory neuroscience. However, the computational principles of perceptual disambiguation are still poorly understood: What drives perceptual decision-making between multiple equally valid solutions? Here we investigate how humans gather and combine sensory information–within and across modalities–to disambiguate motion perception in an ambiguous audiovisual display, where two moving stimuli could appear as either streaming through, or bouncing off each other. By combining psychophysical classification tasks with reverse correlation analyses, we identified the particular spatiotemporal stimulus patterns that elicit a stream or a bounce percept, respectively. From that, we developed and tested a computational model for uni- and multi-sensory perceptual disambiguation that tightly replicates human performance. Specifically, disambiguation relies on knowledge of prototypical bouncing events that contain characteristic patterns of motion energy in the dynamic visual display. Next, the visual information is linearly integrated with auditory cues and prior knowledge about the history of recent perceptual interpretations. What is more, we demonstrate that perceptual decision-making with ambiguous displays is systematically driven by noise, whose random patterns not only promote alternation, but also provide signal-like information that biases perception in highly predictable fashion.

55.15, 6:15 pm **Characterizing late-developing binocular motion mechanisms in human visual cortex** Peter J Kohler[1](pjkohler@stanford.edu), Wesley Meredith[1], Anthony M Norcia[1]; [1]Stanford University, Department of Psychology, Stanford, CA 94305

The visual system can detect motion-in-depth by tracking changes in disparity over time (CDOT), or by computing inter-ocular velocity differences (IOVD). Here we measure responses to these two distinct cues in human visual cortex. We present data from adult (5 experiments, total n=63) and infant participants (n=34) generated using a steady-state VEP design (Kohler et al., VSS, 2016) where random dots moving periodically at 2 Hz generate disparity or 2-D motion, which can be horizontal or vertical and depending on the reference, relative or absolute. The first harmonic of the dot motion frequency will capture responses that differ with motion direction, while the second harmonic will capture responses that do not. The first harmonic was robust only for displays containing horizontal relative disparity cues that produced a strong percept of motion-in-depth. It was weak for conditions with vertical relative disparity, and absent for disparity conditions with no reference, with dots that were uncorrelated or anti-correlated between the two eyes, and without plane-breaking. These findings, and the fact that first harmonic was weak in infants, are consistent with a late-developing image segmentation response that relies on CDOT. The second harmonic was stronger for relative motion than relative disparity, for both vertical and horizontal displays. This effect persisted with uncorrelated and anti-correlated dots. When absolute responses were measurable, absolute disparity produced stronger responses than absolute motion. For infants, disparity also produced stronger responses than motion, and relative and absolute responses were comparable. These findings are consistent with the second harmonic indexing motion-related responses that rely on IOVD, and demonstrate that the weaker responses to disparity compared to 2-D motion are driven by a late-developing mechanism that requires a reference, but not motion-in-depth. This mechanism, likely related to binocular opponent processes, may offer an alternative explanation to psychophysical stereo-movement suppression effects (Tyler, 1971).

Acknowledgement: NIH EY018875-04

55.16, 6:30 pm **Non-isotropic heading errors while moving along curved paths: Another reason to look where we are going?** John A Perrone[1](jpnz@waikato.ac.nz); [1]School of Psychology, The University of Waikato, New Zealand

In order to navigate towards a visual target while moving along a curvilinear path it has been suggested that an active fixation strategy in the direction of the goal provides a simple heuristic for reaching the target (Wann & Swapp, Nat. Neurosci., 2000). Some ground element trajectories become straight when we are on the correct path. This purportedly explains why we look inside of the curve. One problem with this technique is that it only makes use of a small part of the visual flow field that is occurring on the back of the moving eye; a large proportion of the visual flow is not used to help us steer. I have developed a new, visual-vestibular (full-flow field) theory for how we can estimate our rotation while moving along curvilinear paths (Perrone, VSS, 2017). Once the rotation has been measured it can be removed from the combined translation + rotation flow field to derive a heading estimate. This model was tested using a range of line-of-sight directions relative to heading as the simulated observer moved at 1 m/sec over a ground plane towards a wall while on a path curving to the left (rotation rate = 10°/s). A tally of the proportion of times the heading error was less than 2° in each of the four quadrants around (0°, 0°) gave .031, .027, .18, .01. Smaller heading errors occurred when the line of sight was directed down and inside the curved path (quadrant 3). A test against there being equal proportions in each quadrant was significant, χ^2 (3, 289) = 45.1, $p < .001$. The large errors while looking in the other quadrants arise from an unusual lamellar pattern of flow vectors that cause a misperception of the correct rotation direction. Looking in the direction of the curve minimizes these errors.

Acknowledgement: New Zealand Ministry of Business, Innovation & Employment Endeavour grant

55.17, 6:45 pm **Multi-modal representation of visual and auditory motion directions in hMT+/V5** Mohamed Rezk[1](phtawfik@gmail.com), Stephanie Cattoir[2], Ceren Battal[1,2], Olivier Collignon[1,2]; [1]Institut de recherche en sciences psychologiques (IPSY), Universite catholique de Louvain (UCL), Belgium., [2]Center for Mind/Brain Sciences (CiMeC), University of Trento, Italy.

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The human middle temporal area hMT+/V5 is a region of the extrastriate occipital cortex that has long been known to code for the direction of visual motion trajectories. Even if this region has been traditionally considered as purely visual, recent studies suggested that the hMT+/V5 complex could also selectively code for auditory motion. However, the nature of this cross-modal response in hMT+/V5 remains unsolved. In this study, we used functional magnetic resonance imaging (fMRI) to comprehensively investigate the representational format of visual and auditory motion directions in hMT+/V5. Using multivariate pattern analysis, we demonstrate that visual and auditory motion direction can be reliably decoded inside individually localized hMT+/V5. Moreover, we could predict the motion directions in one modality by training the classifier on patterns from the other modality. Such successful cross-modal decoding indicates the presence of shared motion information across the different modalities. Previous studies used successful cross-modal decoding as a proxy for abstracted representation in a brain region. However, relying on series of complementary multivariate analysis, we unambiguously show that brain responses underlying auditory and visual motion direction in hMT+/V5 is highly dissimilar. For instance, our results demonstrated that auditory motion direction patterns are strongly anti-correlated with the visual motion patterns, and that the two modalities can be highly discriminated based on their activity patterns. Moreover, representational similarity analyses demonstrated that modality invariant models poorly fitted our data while models assuming separate pattern geometries between audition and vision strongly correlated with our observed data. Our results demonstrate that hMT+/V5 is a multi-modal region that contains motion information from different modalities. However, while shared information exists across modalities, hMT+/V5 maintains highly separate response geometries for each modality. These results also serve as a timely reminder that observing significant cross-modal decoding is not a proxy for abstracted representation in the brain.

Acknowledgement: FNRS, ERC-MADVIS

55.18, 7:00 pm **Sensitivity to Sensory Cues Predicts Motion Sickness in Virtual Reality** Jacqueline M Fulvio[1](fulvio@wisc.edu), Bas Rokers[1]; [1]Psychology, University of Wisconsin - Madison

Virtual reality (VR) displays can be used to present visual stimuli in naturalistic 3D environments. However, such displays can introduce discomfort, including motion sickness. Some have hypothesized that motion sickness stems from factors related to self-motion and that there are inherent gender differences in VR tolerance (e.g., Riccio and Stoffregen, 1991). We alternatively hypothesize that the discomfort is caused by sensory cue conflicts, which implies that a person's susceptibility to motion sickness can be predicted based on their cue sensitivity. To test our hypothesis, we first measured sensitivity to sensory information in VR. 91 naïve observers viewed 3D motion stimuli in a VR head-mounted display (Oculus Rift). We presented approaching and receding dot motion stimuli at different coherence levels to quantify psychophysical thresholds. Next, we asked participants to watch up to 22.5 minutes of sickness-inducing binocular VR video content. An important difference from previous research is that the VR display was tailored to each individual's inter-pupillary distance (IPD). Observers were free to stop viewing at any time, and we assessed motion sickness symptoms at six points during the experiment using the Simulator Sickness Questionnaire (SSQ). We found that greater cue sensitivity predicted motion sickness, supporting the cue conflict hypothesis. We did not find gender differences: females did not show evidence of greater motion sickness, either in self-reported SSQ scores, or in movie viewing time. We speculate that prior VR results may be related to use of a fixed IPD for all observers. Our results suggest that sensitivity to 3D motion cues can be used as a diagnostic tool to identify individuals prone to motion sickness in VR. Such individuals might benefit from VR media in which specific sensory information is attenuated.

Perceptual Learning: Applied

Tuesday, May 22, 5:15 - 7:15 pm, Talk Room 2

Moderator: Krystel Huxlin

55.21, 5:15 pm **Establishing a preferred retinal annulus (PRA): A new training paradigm to improve vision in patients with central scotoma** Xinyu Xie[1](xiexy518@pku.edu.cn), Lei Liu[2], Cong Yu[1]; [1]Psychology, McGovern Brain Research, and Life Sciences, Peking University, [2]School of Optometry, University of Alabama Birmingham

Current treatment of patients with central scotoma emphasizes the establishment of one preferred retinal locus (PRL). A single PRL may be suitable for viewing nearby targets, but large saccades are required to reach targets on the opposite side of the scotoma, which may cause temporary concealment of the target by the scotoma. One possible remedy is to establish a preferred retinal annulus (PRA) around the scotoma to improve target viewing. Observers with normal vision were trained to identify a blurred tumbling-E target with a 5-deg-radius simulated central scotoma. The target became clear only when it fell into a small window of clear vision contingent to the scotoma edge (Liu&Kwon, 2016). For the PRL group, the clear window was fixed at either left or right side of the scotoma. For the PRA group, it was in the radial direction to the target. Different eye-movement patterns and viewing accuracies emerged after training. The PRL group had the scotoma optimally landed between the initial fixation and target (undershots) in 73% first and 88% second saccades when the target and PRL were on the same side of the scotoma (PRL-near). However, when the target and PRL were on the opposite sides (PRL-far), only 21% first and 41% second saccades optimally landed beyond the target (overshots). Moreover, PRL-far saccades were less accurate than PRL-near saccades, resulting in more target concealments by the scotoma (41% and 43% PRL-far vs. 23% and 7% PRL-near in 1st and 2nd saccades, respectively). The PRA group had mostly optimal undershot saccades (83% first and 91% second saccades), and very few target blockages (16% first and 5% second saccades). These results demonstrated the feasibility and potential functional benefits of PRA training over PRL training. Future experiments will apply PRA and PRL trainings in AMD patients to compare accuracies and efficiencies.

55.22, 5:30 pm **Assessing the trial-by-trial time course of perceptual sensitivity change in perceptual learning using the quick Change Detection method** Zhang Pan[1](zhang2005pan@126.com), Yukai Zhao[1], Barbara Dosher[2], Zhong-Lin Lu[1]; [1]Laboratory of Brain Processes (LOBES), Departments of Psychology, The Ohio State University, [2]Department of Cognitive Sciences and Institute of Mathematical Behavioral Sciences, University of California

Perceptual learning improves perceptual sensitivity through training. The learning curve is typically sampled in blocks of trials because of the number of trials required for each estimation. This results in imprecise and biased estimates of learning. Recently, Zhao et al (2017) developed a Bayesian adaptive quick Change Detection (qCD) method to accurately, precisely, and efficiently assess the time course of perceptual sensitivity change based on the framework of Lesmes, et al. (2009). It selects the optimal stimulus, and updates, trial by trial, a joint probability distribution of the parameters quantifying change in perceptual sensitivity. Here, we implemented and tested the qCD in a 4-alternative forced-choice (4AFC) global motion direction identification task. Five subjects performed 960 trials of the quick CD method interleaved with 960 trials of a 3-down/1-up staircase, with feedback. In each trial, a random dot kinematogram (RDK) moved in a direction (45, 135, 225, or 315 degrees), with coherence on the next trial determined by the qCD or the staircase. On average, training reduced coherence thresholds by 57.3%± 2.1% and 59.9%± 3.0%, estimated with the qCD and staircase, respectively. The qCD could estimate the learning curve either trial-by-trial or as a single exponential learning curve. In the trial-by-trial analysis, the average 68.2% half width of the credible interval (HWCI) of the estimated threshold was 0.031±0.001, 0.024±0.001 and 0.015±0.001 log units after 80, 320 and 880 trials. The averaged HWCI estimated from the entire exponential learning curve was 0.013±0.000 log units, or 0.055±0.003, 0.074±0.003, and 0.018±0.001 log units for the magnitude of learning, time constant and asymptotic level. Additionally, the overall estimates from the two methods matched extremely well, (average r of 0.903±0.022, all p< 0.05).

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The quick CD method precisely and accurately assesses trial-by-trial threshold changes, showing great promise in more precisely characterizing perceptual learning.

Acknowledgement: National Eye Institute grants EY017491 and EY021553

55.23, 5:45 pm **Visual Timing Sensitivity in a World Class Drum Corps** Nestor Matthews[1](matthewsn@denison.edu), Leslie Welch[2], Elena Festa[2]; [1]Department of Psychology, Denison University, [2]Cognitive, Linguistic & Psychological Sciences, Brown University

Introduction: Recent experiments with a world class drum corps revealed modest but reliable visual speed sensitivity differences between color guard experts and low-brass experts (Matthews et al., 2017). Those experiments evaluated speed sensitivity to radial and rotational motion, which register in the human Medial Superior Temporal region (MST) (Smith et al., 2006; Strong et al., 2017). Here we psychophysically investigated whether these two MST-mediated motion types generate group-specific differences on another temporal vision task –temporal order judgments (TOJs). One might predict the finest radially- or rotationally-defined TOJs among color guard members, given their expertise in visually rotating flags synchronously or at precisely specified asynchronies. Alternatively, one might predict the finest TOJs among percussionists, who auditorily divide tempos into precisely specified time intervals, e.g., 32nd notes at 180 beats per minute correspond to ~42 msec periods. Method: Twenty-five percussionists, 67 brass players, and 29 color guard from Drum Corps International's 2016 World Champion "Bluecoats" drum corps viewed bilaterally presented plaids that either radiated or rotated before changing direction asynchronously. Participants indicated whether the direction changed first on the left or right –a temporal order judgment (TOJ). To promote reproducibility, the Open Science Framework (https://osf.io/n7gtj/) contains the complete data set and all software necessary for replicating the study. Results: Percussionists exhibited significantly lower TOJ thresholds than did brass players, who exhibited significantly lower TOJ thresholds than did color guard. Across groups and stimulus conditions, TOJ thresholds spanned an order of magnitude, ranging between 29 milliseconds (percussion; opposite rotational directions) and 290 milliseconds (color guard; opposite radial directions). Additionally, percussionists exhibited significantly faster reactions times than did brass players, who exhibited significantly faster reaction times than did color guard. Conclusion: Visual timing sensitivity may be refined more precisely by percussionists' auditory training than by color guard's visual (rotational and radial motion) training.

Acknowledgement: Denison University Research Foundation

55.24, 6:00 pm **Perceptual learning in police fingerprint detectives.** Parker J Banks[1](banksp@mcmaster.ca), Ralph Gutoskie[2], Allison B Sekuler[1], Patrick J Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University , [2]Department of Forensics, Ontario Police College

The identification of fingerprints collected at a crime-scene is not a computer automated process. Instead, human experts visually match fingerprints to potential suspects. Although it is known that these fingerprint experts are extremely accurate at visual identification (Thompson, Tangen, & McCarthy, 2011), there has been little research on the perceptual learning that accompanies fingerprint training, and thus little opportunity to increase the speed and efficiency with which experts can be trained and complete their work. Therefore, we tested the spatial contrast sensitivity of police fingerprint experts, as they engaged in a 9-week forensic training program at the Ontario Police College. We found that trained experts become more sensitive to coarse details contained at low spatial frequencies, while they remain relatively insensitive to high spatial frequencies. We conducted additional experiments on the relationship between the information present within fingerprints and their identifiability. We found that it is this low-frequency information that is important in determining print identity. The finding that coarse details are vital to fingerprint indentity contrasts with the common notion that experts rely on specific minutiae (Galton, 1893) to identity prints. To allow for the future study of fingerprint identification, we also describe a new latent fingerprint dataset. This dataset consists of hundreds of fingerprints collected from simulated crime scenes, matched to reference, inked fingerprints taken from the same individual. This dataset is freely available, in order to encourage future study of fingerprint expertise.

Acknowledgement: NSERC

55.25, 6:15 pm **Using Eye Tracking to Develop Classification Images for Perceptual Learning** Theodore Jacques[1](tjacq002@ucr.edu), Aaron Seitz[1]; [1]University of California, Riverside

A key question in perceptual learning is what template do participants learn as they train to conduct a given task. While there are a number of approaches that speak to this question, the typical is to generate a classification image based upon noise added to the stimulus that people are trying to discriminate and examining how different noise components contribute to performance. Here we examine a complementary approach where participants search for a low-contrast target on a noisy background. In this way we are able to determine as people learn the extent that their template can be described from the pattern of fixations made as they search for the target and how this changes as they learning the task. The paradigm begins with a pre-test to establish detection thresholds for gabor patches in noise in a predictable location. In the training phase of the experiment, subjects complete a free-viewing search for a near-threshold gabor embedded at an unpredictable location in visual noise using an eye tracker. Subjects are rewarded for finding the target within a set timeframe, and an adaptive procedure maintains an appropriate level of difficulty throughout the training period. We present data to validate the training task, also using pre and post tests to examine transfer. We find reduced thresholds over time for the free-search training task, indicating task-specific learning, but no stimulus-specific improvements in the transfer at post-test. We will also present data showing the extent to which different individuals change how they prioritize noise regions that contain information similar to the task-targets.

55.26, 6:30 pm **Diminished contextual learning in autism spectrum disorders** Ari Rosenberg[1](ari.rosenberg@wisc.edu), Adhira Sunkara[2], Haorui Jiang[1], Ting-Yu Chang[1], Byounghoon Kim[1], Kailey Sabel[3], Sarah Jacquot[3], Ashley Dinges[3], Brittany Travers[3]; [1]Department of Neuroscience, School of Medicine and Public Health, University of Wisconsin-Madison, [2]Department of Surgery, School of Medicine and Public Health, University of Wisconsin-Madison, [3]Kinesiology, University of Wisconsin-Madison

Recent theoretical work suggests that behaviors observed in autism spectrum disorders (ASD) reflect a diminished ability to use contextual information to interpret current sensory information. Here we experimentally test this hypothesis by evaluating multi-session, contextual learning in adolescents with ASD and matched typically developing (TD) peers. In the task, participants view a computer screen divided into four quadrants, search for a visual target (the letter "C") amongst letters "I" and "F", and report the quadrant in which the target is located (9 sessions, 300 trials/session). Unbeknownst to the participants, contextual information about the target location is manipulated across sessions (high context – no context – high context). In the first three and last three sessions, the number of letter I's in a quadrant is proportional to the probability that the target is in that quadrant (high context). In the middle three sessions, no contextual information about target location exists. Search time as a function of the proportion of informative cues in the target quadrant provides a measure of contextual learning. We find that the performance of TD participants strongly modulates across sessions, indicating contextual learning. In contrast, the ASD participants show impaired contextual learning and greater heterogeneity in their learning profiles. Cluster analysis of the search time data specifically reveals two qualitatively distinct ASD learning profiles. The first resembles the TD learning profile, but with a delayed ability to learn, disengage, and then relearn the context. The second fails to learn the context altogether, as indicated by search times that do not modulate with the context manipulation. These results provide experimental evidence suggesting there are at least two unique contextual learning profiles within the autism spectrum. This evidence for distinct learning profiles has practical implications for individualizing treatment and education to maximize therapeutic gains for ASD.

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Health and Human Development (P30 HD003352 and U54 HD090256 to the Waisman Center)

55.27, 6:45 pm **The Psychophysics of Algebra: Mathematics Perceptual Learning Interventions Produce Lasting Changes in the Perceptual Encoding of Mathematical Objects** Philip J Kellman[1](Kellman@cognet.ucla.edu), Everett Mettler[1], Carolyn A. Bufford[1]; [1]Dept. of Psychology, University of California, Los Angeles

Perceptual learning (PL) refers to experience induced improvements in information extraction, including complex pattern recognition that is a hallmark of expertise. Perceptual learning interventions in mathematical domains produce substantial gains on tests of mathematical competence (e.g., Kellman, Massey & Son, 2010). Here we report direct evidence that such perceptual learning modules (PLMs) improve perceptual encoding of mathematical objects, measured psychophysically. In two experiments, accuracy and speed of college students' encoding of equations was assessed in a forced-choice, same-different task with brief exposures. Between a pretest and a delayed posttest, the experimental group completed an Algebraic Transformations PLM, comprised of interactive learning trials requiring mapping of equations across transformations. The aim of the PLM was to improve students' seeing of structure and relationships in algebra; previous research showed that it produced substantial improvements in middle school students' algebra performance. A control group received equal exposure to the same stimuli in a non-mathematical task. On a delayed posttest, the PLM group, but not the control group, showed reliably improved encoding of mathematical objects on the same-different task, even though that task depended solely on physical identity and required no mathematical interpretation. Perceptual learning interventions accelerate expertise in complex domains and produce measurable, durable changes in perceptual encoding.

Acknowledgement: National Science Foundation and US Department of Education

55.28, 7:00 pm **Visual recovery in chronic cortically-blind patients relies on spared cortical activity and increased V1 coverage of the blind field** Antoine Barbot[1,2](antoine.barbot@nyu.edu), Michael D. Melnick[2,3], Matthew R. Cavanaugh[1,2], Anasuya Das[1,2], Elisha P. Merriam[4,5], David J. Heeger[4], Krystel R. Huxlin[1,2,3]; [1]Flaum Eye Institute, University of Rochester Medical Center, [2]Center for Visual Science, University of Rochester, [3]Brain and Cognitive Sciences, University of Rochester, [4]Center for Neural Science, New York University, [5]National Institute of Mental Health, NIMH/NIH

The primary visual cortex (V1) is the major cortical relay of visual information from the retino-geniculate pathway to higher-level, extrastriate areas. V1 damage causes profound, contralateral, homonymous visual-field defects termed cortical blindness (CB). Although perceptual training can recover some visual functions within the blind field of CB patients, the efficiency and limits of visual rehabilitation are constrained by our poor understanding of the neural mechanisms underlying such recovery. Here, we measured visual field sensitivity and cortical activity using Humphrey (luminance detection) perimetry and functional magnetic resonance imaging (fMRI), respectively, in 9 CB individuals prior and following training-induced recovery of global motion and/or static orientation discrimination. Prior to training, visual stimulation of regions with behaviorally normal visual sensitivity generated strong fMRI activity in spared early visual cortex of the damaged hemispheres. Surprisingly, substantial cortical activity was observed upon stimulation of perimetrically blind-field regions. Such brain activity patterns were not observed in control subjects with artificial scotomas, suggesting cortical reorganization of the chronically-damaged visual system. Moreover, we found a direct correlation between the strength of pre-training V1/V2 activity over blind-field regions and the magnitude of training-induced improvement in visual sensitivity at these blind-field locations. No further change in BOLD signal coherence or amplitude was observed following training. However, CB patients exhibited increased V1 coverage of the blind field, consistent with stronger evoked responses and improved luminance-detection sensitivity within the blind field following training. Our results show for the first time that in chronic CB patients, spared pre-training fMRI activity within the blind field can predict areas amenable for training-induced visual restoration. Additionally, training-induced recovery in visual field sensitivity was associated with increased V1 coverage of the blind field. These findings lead us to hypothesize that training recovers vision primarily by enhancing sensory read-out efficiency at blind-field locations represented by strong pre-training V1/V2 activity.

Acknowledgement: NEI grants EY021209 and EY027314 (KH)

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Tuesday Afternoon Posters

Faces: Neural mechanisms 2

Tuesday, May 22, 2:45 - 6:45 pm, Banyan Breezeway

56.301 Intracranial EEG recordings from face-selective temporal cortex show enhanced response to contralateral face information

Brett B Bankson[1,2](brett.bbankson@gmail.com), Edward H Silson[3], Michael J Ward[2], R. Mark Richardson[2], Chris I Baker[3], Avniel S Ghuman[1,2]; [1]Department of Psychology, University of Pittsburgh, [2]Department of Neurosurgery, University of Pittsburgh, [3]Section on Learning and Plasticity, Laboratory of Brain and Cognition, National Institute of Mental Health

Despite behavioral and neuropsychological evidence for a right hemisphere bias for face processing, and a corresponding left hemifield advantage for faces, neurally much remains unknown about the division of labor in face processing between the right and left fusiform. In particular, there remain gaps in our understanding of the role of bilateral face-selective areas in contributing to dynamic representation of face information. To clarify the effects of visual hemifield on bilateral fusiform dynamics, we recorded intracranial encephalography (iEEG) data from 4 patients with electrodes placed directly on right and/or left face-selective temporal cortex. While fixating, participants completed a gender discrimination task in response to 16 face-halves presented individually to the right or left of fixation (4 unique male and female faces divided into 8 left and right halves, yielding 16 unique images). Taking the grand average from the broadband signal, we found that electrodes placed in both right and left temporal cortex show an enhanced response to face-halves presented in the contralateral visual hemifield. This difference between contra- and ipsilateral face-halves emerges within the first 50 ms after stimulus presentation, with both hemispheres showing an early peak at ~160 ms. Signal differences persist throughout the 500 ms following stimulus presentation, with a second peak occurring at ~350 ms in right-lateralized electrodes and ~480 ms in left-lateralized electrodes. We examine identity decoding to determine whether identity processing has a hemifield bias and to assess whether a face-half invariant identity code is seen in the fusiform and when it emerges. Together, these results highlight both early and persistent differences in the hemispheric representational dynamics of face processing based on visual hemifield of stimulus presentation.

56.302 A comprehensive investigation of face recognition lateralisation in the posterior superior temporal sulcus.

Magdalena W Sliwinska[1](m.w.sliwinska@gmail.com), David Pitcher[1]; [1]Department of Psychology, University of York, UK

Introduction FMRI studies have suggested that the right posterior superior temporal sulcus (pSTS) constitutes an important node of a face-selective network required for facial expression recognition. The role of the left pSTS has not been, however, that well investigated. We performed fMRI and TMS studies to investigate the extent to which facial expression recognition in the pSTS is lateralised across hemispheres. FMRI Study A large gender-balanced group of participants (N=52) was scanned while they watched short videos of faces and objects to functionally localize face-selective regions in the whole brain and then compare activation in right and left pSTS with activation in other face-selective regions. Results (Figure) revealed that: - face-selective regions (defined as activation for faces > objects), including pSTS, were present in both hemispheres but they were larger and more consistently found in the right hemisphere; - the right lateralization in pSTS was greater compared to other face-selective regions. These results demonstrate that faces are preferentially processed in the right hemisphere and that the pSTS is the strongest driver of this laterality. TMS Study The hemispheric involvement of pSTS in face recognition was further investigated using TMS. TMS was was delivered to the right and left face-selective pSTS, functionally localised in the fMRI Study, while participants (N=20) performed a facial emotion discrimination task or object discrimination task. Analyses of accuracy data showed that: - TMS over right pSTS impaired discrimination of facial expressions significantly stronger ($p>.001$, corrected) and more consistently (in 18 out of 20 participants) than TMS over left pSTS ($p=.08$, corrected; in 13 out of 20 participants); - TMS had no effect when applied to these homologous regions or a control condition during object recognition task. These results further support the importance of pSTS in face recognition and strong lateralisation of this process in pSTS.

Acknowledgement: Simons Foundation

56.303 Holistic face processing and hemispheric competition during face recognition

Matthew T Harrison[1](mt.harrison@gmail.com), Lars Strother[1]; [1]University of Nevada, Reno

Face recognition relies on holistic visual processing in the right hemisphere and therefore exhibits a left visual hemifield (LVF) half-face bias. We hypothesized that hemispheric competition also contributes to this bias, independently of holistic processing. To test this hypothesis, we performed several face recognition experiments using chimeric faces comprised of hemifield-split half faces. Observers performed a matching task, in which they viewed a target face and then selected a match from two alternatives, one of which differed from the target in either the right or the left half. The first experiment tested whether or not the LVF half-face bias only occurs in the context of a whole face or also applies to half-faces viewed in isolation, in either visual field. Consistent with our hypothesis, we found that the LVF half-face bias only occurs for whole faces viewed with each half in an opposite hemifield. Additional experiments examined the effect of face inversion, which disrupts holistic face processing. While we failed to observe the LVF half-face bias for inverted faces—as predicted by a right hemisphere holistic face processing account of the bias—we nevertheless observed strong hemifield biases. The direction of these biases (i.e., favoring the LVF or RVF) varied across individuals, and therefore did not produce an overall LVF half-face bias for inverted faces. Surprisingly, however, the magnitude of these biases (for inverted faces) correlated with the magnitude of the LVF half-face bias observed for upright faces. This means that the LVF half-face bias for upright faces is not solely due to right hemisphere dominance in holistic face processing. Instead, we propose that it is due to the combined effects of holistic face processing and hemispheric competition during the visual recognition of centrally viewed faces.

Acknowledgement: Research supported by National Institute of General Medical Sciences of the National Institutes of Health, grant number P20 GM103650

56.304 fMRI gender classification of faces, bodies, and common names in the left occipitotemporal cortex

Zhiheng Zhou[1](zhzhou44@gmail.com), Lars Strother[1]; [1]Department of Psychology, University of Nevada, Reno

Visual cues to gender are abundant in the physical properties of faces and bodies. We used fMRI and multivariate pattern analysis (MVPA), combined with a rapid-event stimulus procedure, to explore the neural basis of perceived gender. Unlike previous MVPA studies of face gender perception, we included bodies and common names in our study. We predicted that MVPA could classify the gender of faces and bodies, both in early and category-selective visual cortex. In contrast, we predicted that common gender-specific names (e.g. Ann and Mary versus Bob and Mike) would not be successfully classified using MVPA in early visual cortex. We predicted this because then gender of names is not directly indicated by the physical properties of name stimuli per se. We did, however, predict that name gender could be accurately classified in more anterior brain areas. Additionally, we expected faces and bodies to be better classified in the right hemisphere than in the left, with the opposite expectation for common names. Contrary to our expected results, we found little evidence of accurate MVPA gender classification in early visual cortex for any of our stimulus categories. Instead, successful MVPA gender classification was limited to occipitotemporal cortex, primarily in the left hemisphere, in addition to more anterior brain regions. Maximal MVPA gender classification accuracy was observed in left occipitotemporal cortex, for all three categories of stimuli. Our results are consistent with the role of left occipitotemporal cortex as a visuo-semantic hub involved in gender classification, and perhaps in person perception more generally.

56.305 **FPVS reveals an upper visual field advantage for face categorization** Genevieve L Quek[1](genevieve.quek@uclouvain.be), Bruno Rossion[1]; [1]Institute of Research in Psychology (IPSY) & Institute of Neuroscience (IoNS), University of Louvain

Perceptual asymmetries in vision arise from the brain's preferential response to particular stimulus types at different retinal locations. Where the lower visual field (LVF) outperforms the upper visual field (UVF) in many aspects of low-level vision, increasing evidence suggests the reverse is true for high level face-processing (e.g., sex categorization, Quek & Finkbeiner, 2014; 2016), perhaps due to facilitated projection of UVF inputs to the ventral visual stream. Here we asked whether this UVF advantage extends to face categorization, i.e., the ability to rapidly discriminate variable faces from many other object categories. We recorded 128 channel EEG while 20 participants performed a demanding conjunction target-detection task at central fixation. Simultaneously, we presented two synchronised 6Hz streams of natural object images (e.g., buildings, animals, common objects) 4.3˚ visual angle above and below fixation. Unbeknownst to participants, we embedded face images in the upper and lower object streams at different periodic intervals (1/8 images vs. 1/10 images) within the one minute sequence. This allowed us to capture differential processing of faces vs. objects in the EEG spectrum at each hemifield's face-presentation frequency (i.e., 0.75Hz and 0.60Hz), providing a separate yet simultaneous index of UVF and LVF face categorization. Consistent with previous studies, the common visual response at 6Hz was characterised by a central occipital topography, whereas face-selective activity was strongest over right occipito-temporal channels. Importantly, and as predicted, this differential response to faces amongst objects was much stronger in the UVF than the LVF. A control experiment (N=12) in which we stimulated the UVF and LVF on separate trials indicated that this increased face-selective activity for UVF faces could not be attributed to a general increase in visual processing in this region. Taken together, our results suggest the UVF advantage demonstrated for face-sex discrimination also extends to rapid face categorization.

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56.306 **Spatiotemporal dynamics of view-invariant face identity perception** Joan Liu[1](joan.liu@uclouvain.be), Charles C.-F. Or[2], Bruno Rossion[1]; [1]Psychological Sciences Research Institute & Institute of Neuroscience, University of Louvain, Belgium, [2]Division of Psychology, School of Social Sciences, Nanyang Technological University, Singapore

In everyday life, humans recognise individual faces at a glance despite substantial variations in their appearance, e.g., due to changes in head orientation. Here, we investigated the neural mechanisms underlying rapid view-invariant face identity perception with electroencephalography (EEG) and a fast periodic visual stimulation paradigm. We measured individual face discrimination responses for upright and inverted faces across 4 ranges of viewpoint variations: 0° (no change), ±30°, ±60°, ±90° in separate 60-s stimulation sequences. In each sequence, images of one face identity were displayed at a rate of F=6 Hz (6 images/s) and interleaved with different face identities at fixed intervals every 7th face (F/7 Hz=0.86 Hz). At every stimulation cycle, faces varied randomly both in size (80-120%) and in viewpoint, within a predefined range. For example, in the ±90° condition, faces varied between –90° (left profile) and +90° (right profile) in steps of 5°. Periodic EEG responses at 6 Hz captured general visual processing of the face stimuli, while those at 0.86 Hz and harmonics captured identity discrimination. In the frequency-domain, all observers (N=17) showed significant face discrimination responses for upright faces, which peaked over bilateral occipito-temporal regions and decreased with increasing viewpoint variation (~50% response reduction between 0° and ±90° viewpoint variations), reflecting robust but view-sensitive processing of face identity. Decomposing the discrimination responses in the time domain revealed that this viewpoint sensitivity was driven by an early (~200–300 ms) component, while a later (~300–600 ms) component maintained stable, significant amplitudes across all viewpoint variations, indicative of view-invariant processing. Note that both components shared similar bilateral occipito-temporal topographies. Face inversion significantly decreased both view-sensitive and view-invariant responses by ~60-80%, pointing towards the involvement of face-specific processes. These findings suggest two distinct temporal stages of view-dependency in high-level representations of face identity in the human visual system

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56.307 **Rapid decoding of face identity, familiarity, gender and age** Katharina Dobs[1](kdobs@mit.edu), Leyla Isik[1], Dimitrios Pantazis[1], Nancy Kanwisher[1]; [1]Massachusetts Institute of Technology

Considerable evidence from behavioral and neural studies indicates that faces are detected rapidly. However, a face reveals not just the presence of a person, but many different kinds of information about that person, such as their gender, age, familiarity and specific identity. How quickly are these specific dimensions of face information represented? To find out, we used Magnetoencephalography (MEG) and decoding techniques to measure the time course of extraction of each of these dimensions of face information. Subjects (n = 5) performed a one-back task while viewing 80 different face images; each image was repeated 25 times. The stimulus set consisted of five different images from each of 16 different celebrities. We chose the celebrities such that half of them were familiar (US actors) versus unfamiliar (German actors), young (< 36 years) versus old (> 59 years), and female versus male. MEG decoding accuracy was computed separately at each time point (10 ms bins) after stimulus onset based on stimuli that varied in lighting, pose and orientation (for face identity decoding), and across individuals (for familiarity, gender and age decoding). In each subject individually, we could decode all dimensions of face information within the first 150 ms after stimulus onset (mean peak decoding accuracy about 70% for binary dimensions, and about 30% for 16-way identity). This decoding of face dimensions occurs at shorter latencies than position and size invariant object category decoding (Isik et al 2014). Further, these results cannot be easily explained by low-level differences, because all face dimensions could be decoded rapidly, whether they contained discriminative low-level features (e.g. age) or not (e.g. familiarity) as measured by decodability from early layers of a face deep neural network (VGG-Face). Overall, our results indicate that many different dimensions of face information become available extremely rapidly, within 150 ms of stimulus onset.

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56.308 **Multivariate classification of EEG data reveals spatial frequency dominance patterns during broad band image processing** Kirsten Petras[1](kirsten.petras@uclouvain.be), Christianne Jacobs[1], Sanne Ten Oever[2], Valerie Goffaux[1,2]; [1]Psychological Sciences Research Institute (IPSY), Université Catholique de Louvain, [2]Department of Cognitive Neuroscience, Faculty of Psychology and Neuroscience, Maastricht University

The spatial frequency (SF) spectrum is one of the most fundamental visual properties; it has profound effects on how a stimulus is processed throughout the visual system. Despite visual input being broadband by nature, past studies have investigated SF processing mainly by presenting observers with stimuli containing either one single frequency or a narrow band of frequencies. How and when distinct SFs contribute to the visual processing of natural broadband input is therefore largely unknown. Using EEG recordings and multivariate decoding techniques we were able to trace the processing of individual frequency bands during the processing of broadband images. We presented 21 participants with images of human and monkey faces, as well as their phase scrambled versions. Images were filtered to contain either low SF only, high SF only, or the sum of both resulting in a broadband spectrum. We trained support vector machine classifiers to differentiate high SF from low SF trials using the narrowband trials as training data. We then evaluated those classifiers on trials in which participants saw broadband stimuli containing both high and low SFs. We found a distinctive pattern of SF dominance over time that differed between intact and scrambled images and human and monkey faces with stronger low SF dominance for intact images and particularly for human face images, within the latency range of the N170 event-related potential. This finding provides evidence for SF specific processing of broadband stimuli, consistent with predictive coding models of vision. Interestingly, stimulus category modulates the pattern

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of SF dominance indicating a high-level influence on fundamental visual processing stages. With this study, we demonstrate for the first time, that multivariate decoding techniques can be used to track SF processing in naturalistic broadband stimuli.

56.309 **Predicting the location of macaque face patches with functional connectivity** David E Osher[1](osher.6@osu.edu), Josh Fuller-Deets[2], Bevil Conway[3]; [1]Dept. of Psychology, The Ohio State University, [2]National Institute of Health, [3]National Institute of Health

Patches of face-selectivity in macaque inferotemporal cortex have been identified with fMRI for over a decade, and have since been investigated with great interest. However, little is known about the mechanisms that bring about intersubject variability in the location and degree of activation in these face patches. Why do they vary in location? Why do some monkeys lack some of these patches altogether, while others demonstrate very strong selectivity? The neural architecture that may underlie an individual macaque's specific and idiosyncratic activation pattern remains unexplored. Since connectivity is the principle aspect of neural architecture that defines what a brain region is capable of computing, we hypothesized that connectivity should be strongly predictive of macaque face patches. We used intrinsic functional connectivity to model and predict the location and activation strength of each monkey's face patches, in two monkeys. The resulting model describes the connectivity fingerprint for face selectivity in the macaque brain, offering potential targets for optogenetic or pharmacological manipulations outside of the traditional set of face patches. Importantly, this approach allows researchers interested in electrophysiological experiments to infer the location of face patches using an individual macaque's connectivity data, which can be acquired with minimal or no training, saving researchers years of experimental preparation.

56.310 **Functional connectivity of ventral temporal cortex reveals category-specificity in medial parietal areas** Adam D Steel[1,2](adam.steel@nih.gov), Edward H Silson[1], Chris I Baker[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, [2]Wellcome Trust Centre for Integrated Neuroimaging (WIN), FMRIB Centre, University of Oxford

Medial parietal cortex contains a scene-selective region (medial place area, MPA) that shows strong functional connectivity to anterior parahippocampal place area (PPA). It has been posited that MPA is an interface between perceptual and memory processes (Silson et al., 2016). However, it is unclear whether selectivity for other categories is also present within this region. Here, we investigate the functional topology of medial parietal cortex based on its resting-state functional connectivity with ventral temporal cortex (vTC) and compare this organization to stimulus-evoked activation. Resting state fMRI was collected in 42 subjects and aligned to a standard surface mesh. Posterior, medial, and anterior regions of vTC were anatomically defined by dividing the fusiform gyrus and collateral sulcus along their posterior-anterior axis, corresponding to divisions of FFA and PPA, respectively. Using multiple regression, the unique functional connectivity of each region was calculated for each subject. Medial parietal cortex was parcellated based on its connectivity to the vTC regions. This analysis revealed two adjacent regions anterior to the parietal occipital sulcus that show strong differential connectivity to anterior PPA and FFA. Preferential connectivity to anterior PPA overlapped with MPA, and preferential FFA connectivity was immediately anterior. The category selectivity of the medial parietal parcels was calculated using an independent dataset acquired in a separate group of subjects. The PPA-preferring region had a larger response to scenes than other categories, while the FFA-preferring region had a larger response to faces than other categories. Therefore, these results suggest that category specificity may be preserved in regions of medial parietal cortex.

56.311 **Neural Correlates of Holistic Face Processing** Celia Foster[1,2,3](celia.foster@tuebingen.mpg.de), Mintao Zhao[1,4], Andreas Bartels[1, 3, 5, 6], Isabelle Bülthoff[1]; [1]Max Planck Institute for Biological Cybernetics, Germany, [2]Graduate Training Centre of Neuroscience, International Max Planck Research School, University of Tübingen, Germany, [3]Centre for Integrative Neuroscience, Germany, [4]School of Psychology, University of East Anglia, UK, [5]Department of Psychology, University of Tübingen, Germany, [6]Bernstein Center for Computational Neuroscience, Tübingen, Germany

Holistic processing is the tendency to perceive an object as an indecomposable whole rather than by its parts. Psychological research has shown that faces are processed holistically. However, recent studies have shown that non-expertise objects with salient Gestalt information are also processed holistically, questioning whether this phenomena is unique to faces. Neuroimaging studies have linked holistic processing of faces to brain activity in face-responsive regions of the occipital-temporal cortex. However, these studies specifically localized face-responsive brain regions, but not object, scene or perceptual grouping related brain regions. In this study, we aimed to explore the neural correlates of holistic face processing in a larger range of brain regions, in order to investigate how specific the activation is to face regions. We used fMRI to record the brain activity of subjects performing a composite face task. Participants viewed pairs of faces and determined whether the top halves of the faces were the same or different. Additionally, we localized specific regions of interest defined by their responses to faces, objects, scenes and perceptual grouping, allowing us to investigate how activity in these regions changed during the composite face task. Surprisingly, we found that activity in the occipital face area, fusiform face area and anterior temporal face area did not show a clear pattern of activity relating to the behavioural composite effect. However, activity in the parahippocampal place area, superior parietal lobule and early visual cortex all showed a pattern of activity consistent with the behavioural composite effect. These results suggest that holistic processing occurs in brain regions involved in spatial processing, perceptual grouping and early vision, rather than being limited to face-responsive brain regions. We hypothesize that holistic perception may be driven by these factors rather than identity discrimination, in line with the behavioural finding of the composite effect in non-expertise objects.

56.312 **Repetitive TMS to right OFA enhances part-based but not holistic face encoding** Elyana Saad[1,2], Joseph M. Arizpe[1,2], Michael Esterman[2,3], Joseph M. DeGutis[1,2]; [1]Department of Psychiatry, Harvard Medical School, United States, [2]VA Boston Healthcare System, United States, [3]Department of Psychiatry, Boston University School of Medicine, United States

Prominent face processing models suggest that the right occipital face area (rOFA) processes facial feature information, though several studies suggest that rOFA may play a role in holistic face processing. We sought to test the role of the rOFA in holistic by using the classic part-whole paradigm. In particular, we tested the effects of repetitive transcranial magnetic stimulation (rTMS) concurrently with a delayed-matched-to-sample version of the part/whole paradigm. Participants studied a whole face for 1-sec (the target) and were required to match it from memory after a brief (1-sec) delay to one of 2 exemplars at probe (a match to the target, and a non-match). During whole trials, the non-match whole face included selective featural modifications (eyes or nose or mouth). During part trials, the probe stimuli included isolated features (either eyes or nose or mouth). To assess holistic and featural face processing within the right occipital face area (rOFA), 10Hz rTMS was delivered for 300ms prior to the encoding period of the target. We used the right middle temporal area (rMT) as a control region, an area not specialized in face processing. Additionally, we had baseline blocks where TMS was not delivered. During the session the order of the rOFA, rMT, and baseline blocks were interleaved and counterbalanced. Our results show that compared to baseline and rMT, rTMS applied to the rOFA prior to target presentation decreased the holistic advantage. This pattern cannot be explained by speed-accuracy tradeoff. These results suggest that rOFA is implicated in holistic face processing.

56.313 **Is there a Bias to Encode Peer Faces in the FFA?** Junqiang Dai[1,2](junqiang.dai@gmail.com), Suzy Scherf[1,2]; [1]Psychology Dept. Penn State University, [2]Social, Life, and Engineering Sciences Imaging Center, Penn State University

Our work indicates that emerging adults, individuals ages 18-25 years, have a peer bias in their face recognition abilities (Picci & Scherf, 2016). Specifically, they exhibit superior recognition for peer faces compared to faces from other developmental groups. Little is known about how the underlying neural circuitry is organized to support this peer bias. Here, we examined neural activation in emerging adults as they viewed faces from a wide range of developmental groups while they were scanned with fMRI. The face categories included children, early puberty adolescent, late puberty adolescent, emerging adult (i.e, peer), and parent faces. For each participant, we individually defined FFA regions of interest (ROI) bilaterally using each face category contrasted with objects (e.g., child faces – objects, emerging adult faces – objects). We quantified each ROI in terms of the magnitude of response to each category of faces, the number of active voxels, and the locus of activation. We found that the right FFA activation was largest in volume when defined by emerging adult faces than by any other face category. In addition, the emerging adult right FFA region was in a more anterior location compared to the other face defined FFA ROIs, particularly in comparison to the child-face defined FFA. Finally, each of the face category defined FFA ROIs exhibited a unique profile of activation, which suggest that the bilateral fusiform gyri appear to encode information about the developmental stage of a face in separate, but overlapping, patches of tissue. In sum, the findings suggest that the peer bias in emerging adult face recognition behavior may be subserved by disproportionally larger activation of neural tissue located in an anterior part of the FFA (but not FFA2) compared to that elicited by other kinds of faces.

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56.314 **An Investigation of Neural Mechanisms for Reversed Inversion Effect in Learning Faces Varying in Pose** Gary C.W. Shyi[1,2,3](cwshyi@gmail.com), Peter K.-H. Cheng[2,4], Becky Y.-C. Chen[1,2], Tina S.-T. Huang[1,2], Alex Y.-C. Kuo[1,2], Yun Lee[1,2]; [1]Department of Psychology, National Chung Cheng University, Taiwan, [2]Center for Research in Cognitive Sciences, National Chung Cheng University, Taiwan, [3]Advanced Institute of Manufacturing with High-tech Innovations, National Chung Cheng University, Taiwan, [4]Research Center for Education and Mind Sciences, National Tsing Hua University, Taiwan

Our previous studies have shown that multiple exposures coupled with sufficient pose variation can lead to robust recognition and significant generalization (Shyi & Lin, 2014; Cheng & Shyi, 2014). However, only upright faces were tested in those studies. Here we investigated whether it would be possible to train participants to learn about inverted faces with the same set of manipulations that have been used to learn about upright faces. The results revealed both significant learning and generalization of inverted faces comparable to their upright counterparts. Further analyses, revealed that compared to upright faces, the learning of inverted faces was contaminated with an inflated rate of false positives, suggesting that there was actually very little learning of inverted faces. Somewhat surprisingly, we also found evidence implicating a reversed inversion effect where inverted faces during learning yielded significant generalization when they were tested upright during recognition test. To understand the possible neural mechanisms that may account for the reversed inversion effect, we asked participants to perform a one-back task and judged whether the identity of currently viewed face was the same as the immediately preceding one. They made the judgment while viewing sequences of animation portraying rotation in pose. Structural and functional images of brain regions selective for face processing were acquired. The results showed brain activations for both upright and inverted faces underwent pose rotation were greater than that for scrambled controls. Furthermore, while areas underlying the core face system were activated in processing both upright and inverted faces, stronger activations of bilateral OFA and FFA were found processing inverted than processing upright faces. We suspected that the greater involvement of bilateral face-selective regions may reflect more processing and hence better learning of facial features, but not configuration, comprising inverted faces, which in turn may have led to reversed inversion effect.

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56.315 **The neural basis of face ensemble processing: An EEG-based investigation of facial identity summary statistics** Tyler Roberts[1](tyler.roberts@mail.utoronto.ca), Jonathan S Cant[1], Adrian Nestor[1]; [1]Department of Psychology at University of Toronto Scarborough, Scarborough, ON

Extensive behavioural work has documented our ability to extract summary statistics from groups of faces such as average emotion, gender, and identity. However, to date little is known about the neural mechanisms subserving the extraction of summary statistics from face ensembles. Here, we used electroencephalography (EEG) to examine and compare the neural processing of facial identity from ensembles and single faces. To this end, we collected EEG data across 14 participants who viewed ensembles composed of 6 faces as well as single faces presented one at a time. Critically, ensembles were designed such that, though they consisted of different individual faces, they could lead, half of the time, to the same summary representation (i.e., to the same average face), and, half of the time, to different summary representations. Pattern analyses were then conducted across spatiotemporal signals recorded from 12 bilateral occipitotemporal electrodes. These analyses found, first, that single faces can be well discriminated from their corresponding EEG signal, consistent with previous work. Second, ensembles with different average identities, but not those with the same average identity, could be discriminated from each other above chance. Third, critically, classifiers trained on ensembles with different average identities were able to successfully discriminate their corresponding average identities presented as single stimuli. Finally, face ensembles and single faces exhibited different time courses of discrimination. Specifically, ensemble discrimination reached significance earlier, but peaked later than single-face discrimination, suggesting an extensive interval of evidence accumulation and information processing (i.e., average identity extraction). Thus, to our knowledge, the present findings provide the first evidence based on EEG data regarding the extraction of summary statistics from face ensembles. Further, they serve to characterize the temporal profile of ensemble processing and its relationship with single face recognition.

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56.316 **Putting the face and body back together: The neural representation of the whole person** Libi Kliger[1](libi.stein@gmail.com), Galit Yovel[1,2]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

Numerous fMRI studies have examined the representation of faces and headless bodies in the face-selective and body-selective brain areas. However, in real life our visual system is exposed to the face and body attached together and it is therefore of interest to understand how face and body-selective areas represent the whole person. The few studies that examined this question tested whether the response to the whole person equals or deviates from the mean of the response to the face and body. However, a deviation from the mean may reflect several possible responses: The whole person may be equal the max response of the preferred stimulus (i.e., the response to the face alone in face areas or body alone in body areas); a weighted mean of the response to the face and body in which the weights differ from 0 and 1 (non-max responses) or the sum of the response to the face and body. Here we used two methods that allowed us to directly examine each of these different models: a single-voxel based approach that models the response to a person as the sum of responses to the face and the body with an interaction term; a multi-voxel based approach that models the response to the person using a linear combination of the responses to the face and the body (Reddy et al. 2009). Both methods revealed very similar findings. The fMRI response to the whole person was consistent with a weighted mean response, with most responses close to the max response, indicating a large influence of the preferred stimulus on the response to the whole person. These findings suggest relatively little influence of the response of the non-preferred stimulus on the preferred stimulus even when both are parts of the same stimulus.

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56.317 **Differential responses across body- and face-selective cortex predict visual categorization behavior** Mona Rosenke[1](rosenke@stanford.edu), Nicolas Davidenko[2], Kalanit Grill-Spector[1,3], Kevin S Weiner[1]; [1]Department of Psychology, Stanford University, Stanford, CA, [2]Center for Statistical Analysis in the Social Sciences, Cowell College,University of California Santa Cruz, [3]Stanford Neuroscience Institute, Stanford, CA

Humans categorize objects remarkably fast. Prior research shows that neural responses within a single region are correlated with categorical judgments of visual stimuli, which likely contributes to this efficient behavior. However, it is presently unknown if not just one, but instead, several functional regions that are adjacent in cortex may work together to perform categorical judgments. Here, we leveraged the fact that regions selective for faces and bodies are adjacent in human ventral temporal cortex (VTC) to test if and how responses from both types of regions contribute to categorical judgments. To do so, we generated a novel set of parameterized silhouette stimuli that spanned a continuous morph space between faces and hands, while controlling for low-level image properties. We defined stimuli at 5 morph levels, ranging from fully face-like (level-1) to fully hand-like (level-5), and behaviorally calibrated intermediate (level-3) stimuli to appear equally face-like and hand-like in a large group of participants (N>60). Using these stimuli, we conducted two types of experiments in 14 independent participants: (i) an fMRI block-design experiment during which we measured mean responses in face- and body-selective regions in VTC and (ii) a behavioral categorization experiment. This two-pronged approach allowed us to examine the relationship between neural responses and behavioral categorization. We report three main findings. First, adjacent face- and body-selective regions in VTC illustrate functionally distinct neural tuning to face-hand morphs. Second, neural tuning is correlated with behavioral categorization judgments (R2 range: .35 - .54). Third, a linear regression model reveals that the combination of neural responses of face- (b=.31) and body-selective (b=-.22) regions best predicts human judgements (cross-validated R2: .70±16). Together, these findings support a new idea in which the differential response between regions selective for different domains more accurately explains human categorical judgements than neural responses from one domain-selective region alone.

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Faces: Familiarity and other-race effects

Tuesday, May 22, 2:45 - 6:45 pm, Banyan Breezeway

56.318 **A neural index of rapid and automatic recognition of face familiarity** Xiaoqian Yan[1](yanxqpsy@gmail.com), Bruno Rossion[1]; [1]Psychological Sciences Research Institute, Institute of Neuroscience, University of Louvain, Belgium

Humans have an astonishing ability to rapidly and automatically recognize a face as being familiar among a crowd of unfamiliar faces. To capture this process while mimicking the rapid processing strain we experience in daily life, we used a Fast Periodic Visual Presentation (FPVS) approach coupled with electroencephalography (EEG). Fifteen participants viewed 12 sequences of natural images of different unfamiliar faces alternating at a frequency of 6 Hz (i.e., 6 faces by second) over 70 s. Variable familiar faces (i.e., different face images of French celebrities) appeared every 7th image. Participants were unaware of the goal of the study and performed an orthogonal task of responding to color change of a central fixation cross. A robust familiar-unfamiliar discrimination response was objectively identified in the EEG spectrum exactly at 6/7 Hz (0.857 Hz) and its harmonics over bilateral occipito-temporal regions, in all individual participants. Image variability ensured that this familiarity face response was not due to low-level cues, as confirmed by its large reduction for faces presented upside down (about 15% of the response to upright faces, barely above noise level). Fourteen out of 15 subjects had significant face inversion effect over either unilateral or bilateral OT region. The familiarity face response started at about 200ms following stimulus onset and lasted for about half a second. By providing a robust index of human ability to rapidly and automatically recognize a face as being familiar among unfamiliar faces, our study opens new perspectives for understanding the nature and spatio-temporal course of this function as well as for characterizing it in clinical and developmental populations.

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56.319 **Face Familiarity in Deep Convolutional Neural Networks** Eilidh C Noyes[1](eilidh.noyes@utdallas.edu), Y. Ivette Colon[1], Matthew Q Hill[1], Connor J Parde[1], Carlos D Castillo[2], Swami Sankaranarayanan[2], Alice J O'Toole[1]; [1]School of Behavioral and Brain Sciences, The University of Texas at Dallas, USA, [2]University of Maryland Institute for Advanced Computer Studies, USA

Human face recognition is robust in difficult image conditions for people we know, but not for unfamiliar people. This familiarity advantage holds even for disguised faces (Noyes & Jenkins, 2016). Previously, we tested a deep convolutional neural network (DCNN) developed for face recognition (Sankaranarayanan et al. 2016) on its identity-matching performance on disguised and non-disguised faces. The DCNN performed well for non-disguised and impersonation image pairs, but not for evasion disguises (i.e., disguised to look unlike oneself) (Noyes et al. 2017). Here, we asked whether this same DCNN could overcome disguise when it becomes "familiar" with an identity. Face representations were extracted from the top layer of the network. The DCNN's task was to decide if image pairs were of the same person. We compared two familiarization methods. In the feature averaging method, same/different identity decisions for each image pair were made by comparing the averaged DCNN features of the "familiarized identity" to the DCNN features in a comparison image. This simulated an average representation of a known face. DCNN feature averaging improved matching accuracy on evasion disguise faces from 50% to 69%, however it impaired performance on different-person disguise and non-disguise trials. Next, we tested an identity contrast method in which the DCNN learned each identity, in turn, from ~100 in-the-wild images that were contrasted against images of all other identities from the database with a Support Vector Machine. The DCNN face representations of the matching task images were then compared for similarity with the DCNN representations of each of the learned identities. The identity contrast method resulted in a 16% improvement in accuracy for evasion disguise faces, and importantly also maintained high performance for different person trials. In conclusion, the DCNN benefited from familiarization and exhibited between- and within-person learning that is similar to humans (Noyes, 2016).

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56.320 **Comparing the perceptual separability of familiar and unfamiliar face dimensions** S. Sanaz Hosseini[1](shoss030@fiu.edu), Fabian A. Soto[1]; [1]Department of Psychology, Florida International University

Previous research suggests that learning to categorize objects along a given dimension produces changes in the perceptual representation of that dimension, including an increase in its perceptual separability (i.e., the dimension's representation staying relatively invariant across changes in other dimensions). This suggests that object dimensions representing variation in familiar categories, such as face gender and race, might show higher perceptual separability from other dimensions than completely novel stimulus dimensions, such as unfamiliar identity. Three groups of participants completed different identification tasks involving four faces, which resulted from the combination of two levels of facial expression (neutral and sad) and two levels of a second, target dimension. For group Id, the target dimension was composed of two unfamiliar identities, both caucasian males. For group Gn, one of the unfamiliar identities was replaced by a female, making gender the target dimension. For group Rc, the same unfamiliar identity was replaced instead by an asian male, making race the target dimension. A model-based analysis using General Recognition Theory with Individual Differences (GRT-wIND) showed violations of perceptual separability for all dimensions in all groups, but these were stronger for the unfamiliar identity dimension than for the familiar gender and race dimensions. Violations of perceptual separability for the emotion dimension were also stronger when it was paired with the unfamiliar identity dimension than when it was paired with the familiar gender and race dimensions. These results suggest that perceptual separability of a face dimension correlates with its familiarity, and that categorization in the natural environment (e.g., by gender and race) may have similar influences on dimension representation as categorization training in experimental settings.

56.321 Implicit recognition of one's own and familiar faces Ilona Kotlewska[1,2,3](ilona.kotlewska.was@dartmouth.edu), Matteo Visconti di Oleggio Castello[1], Anna Nowicka[2], Maria I. Gobbini[1,4]; [1]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA, [2]Nencki Institute of Experimental Biology of Polish Academy of Sciences, Warsaw, Poland, [3]Faculty of Humanities, Nicolaus Copernicus University, Torun, Poland, [4]Dipartimento di Medicina Specialistica, Diagnostica e Sperimentale (DIMES), Medical School, University of Bologna, Bologna, Italy

Introduction Behavioral evidence suggests that personally familiar faces (PFF) are processed in prioritized way (Gobbini et al., 2013; Visconti di Oleggio Castello et al., 2014; 2017; Visconti di Oleggio Castello & Gobbini, 2015). However, the mechanisms for facilitated detection of PFF is still matter of investigation. Moreover, the advantage of one's own face over other familiar faces has not been confirmed (Bortolon et al., 2017). Here, we tested if fast detection of PFF precedes explicit recognition of identity. Fast responses toward one's own and PFF were measured with a saccadic choice task and explicit recognition of identity – with a manual response. Method In a saccadic choice task two images of faces (familiar target and unfamiliar distracter) were presented simultaneously in the left and right visual fields (Crouzet et al., 2010, Visconti di Oleggio Castello & Gobbini, 2015). Participants were instructed to move their eyes towards familiar face (among them one's own face was presented). Stimuli were presented for 16, 32, or 80 ms, followed by a mask. Saccadic responses were measured with an eye-tracker. After a saccadic response, participants reported the identity of the familiar face. Results Preliminary data indicated that the accuracy of saccadic responses towards PFF was significantly higher than accuracy for manual responses for 16 ms presentation. Explicit identification of participants' own faces was more accurate compared to familiar faces recognition at the presentation time of 32 ms. For 80 ms presentation saccadic and manual responses remained highly accurate for both PFF and self-face. Conclusions Participants were able to detect familiar faces without explicit recognition. The advantage of one's own face detection over familiar faces was found only for the 32 ms presentation. Lack of differences in shorter and longer times of exposure (16 & 80 ms) suggests that PFF are perceived as efficiently as self-face.

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56.322 Analytical Match-Mismatch Detection with Holistically Processed Faces Mitchell A Meltzer[1](mitchell.meltzer@utdallas.edu), Anjali Nair[1], John P Quinonez[1], James C Bartlett[1]; [1]School of Brain and Behavioral Sciences, The University of Texas at Dallas

How do observers distinguish previously viewed faces from new faces containing old parts? Meltzer et al. (see VSS, 2016; VSS, 2017) proposed that this type of configural recognition is based on familiarity differences – old faces evoking stronger familiarity than new faces with old parts – in conditions supportive of holistic or "unitized" encoding. By contrast, configural recognition is based on conjunctive representations supporting an analytical process of match-mismatch detection in conditions disruptive to holistic processing. In tests of this hypothesis, participants studied lists of well-formed, upright faces or faces that were inverted and/or misaligned to disrupt holistic processing. In the subsequent test, participants viewed a sequence of faces, responding to each with an old-new judgment for (a) the upper half of the face, (b) the lower half of the face, and (c) the face as a whole. The accuracy of whole-face judgments was controlled by adjusting study-presentation frequency to match configural recognition across stimulus conditions. With such matching in place, the key finding was that high-confidence recognition of facial parts was consistently more accurate with inverted and misaligned faces than with well-formed upright faces. One interpretation of our findings is that holistic processing impairs the formation of conjunctive representations that support match-mismatch detection. An alternative view is that the formation of conjunctive representations occurs independently of holistic processing as a function of study time. To test these ideas, we employed the paradigm described above with upright and inverted faces, each studied two or eight times. The results suggest that conjunctive representations supporting match-mismatch detection are formed at least as efficiently with upright faces (allowing for holistic processing) as with inverted faces (disrupting such processing) with repeated stimulus exposures. These findings have important implications for the role of holistic processing in recognition memory for newly learned faces.

56.323 Decisional space modulates saccadic reaction times towards personally familiar faces in healthy observers and acquired prosopagnosia Meike Ramon[1](meike.ramon@gmail.com), Nayla Sokhn[1], Junpeng Lao[1], Roberto Caldara[1]; [1]Visual and Social Neuroscience, Department of Psychology, University of Fribourg, Fribourg, Switzerland

The speed of visual object categorization has been studied with manual Go/No-go paradigms and saccadic reaction time (SRT) paradigms. SRT paradigms require observers to perform choice saccades between parafoveally presented stimuli towards a predefined target category, and provide a more precise description of the lower bound of processing speed. According to a recent study (Visconti di Oleggio Castello & Gobbini, 2015) rapid saccades towards personally familiar (PF) faces can be performed by healthy observers within 180ms. However, this study used a limited number of PF faces, which differed between the few (n=7) observers tested, two of which performed at or near chance level. We tested different cohorts of healthy observers and PS, a case of acquired pure prosopagnosia, to investigate visual categorization across three SRT experiments that controlled for task constraints and breadth of decisional space. Observers performed one gender, and two familiarity categorization tasks. The latter differed in terms of the decisional space, as observers were required to saccade towards one of few, or many possible targets, respectively. Our findings show that healthy and impaired observers' performance varies as a function of decisional space. All observers, including PS, performed binary gender decisions most efficiently; however, the distribution of PS's SRTs differed fundamentally from those of healthy observers. For familiarity decisions, target search for fewer identities was associated with more accurate behavior and faster SRTs. Importantly, like PS, numerous healthy observers' performance was at chance level for familiarity decisions. These observations stress the importance of considering task constraints and procedural aspects in SRT paradigms when attempting to determine processing speed using forced-choice categorizations. Our findings dispute the previous interpretation of SRT modulation attributed to personal familiarity (Visconti di Oleggio Castello & Gobbini, 2015); we argue that rapid SRTs towards PF faces can be entirely accounted for by decisional space constraints.

56.324 Ethnicity and gender effects in the perception of age in faces Seyed Morteza Mousavi[1,2](smousavi92@gmail.com), Mengqi Chen[2], Ipek Oruc[2]; [1] Graduate program in Neuroscience, University of British Columbia, [2]Department of Ophthalmology and Visual Sciences, University of British Columbia

Observers recognize faces of their own race more easily than other-race faces. This is attributed, in part, to differential experience with faces of unfamiliar ethnicities. Furthermore, differential experience is known to also have an impact on other aspects of face perception such as gender categorization (O'Toole & Peterson, 1996). One study found evidence for other-race effects in age perception in a group of African observers, though this effect was not present in the Caucasian group (Dehon & Brédart, 2001). Here, we investigated age perception in East Asian and Caucasian observers who viewed 288 faces that ranged in age from 18 to 89 years old (1:1 race and gender ratio). Observers' average age estimates increased monotonically with the true age of the face stimuli. Accuracy for age estimation was maximal for the middle age range, while age was overestimated for younger faces, and underestimated for older faces. Overall, Caucasian faces and male faces were perceived to be older than East Asian and female faces, respectively. Female observers overestimated age of male faces by one year, though these faces were perceived veridically by male observers. There was no such difference in the perception of female faces, which were slightly underestimated by both female and male observers. Importantly, perception of age in other-race faces showed a bi-phasic pattern that switched between over- and under-estimation of age around 42-47 years of age for both groups of observers. East Asian observers rated Caucasian faces older and East Asian faces younger than

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did Caucasian observers before this age boundary. The pattern reversed after this age range. These results reflect physiognomic features in Caucasian and East Asian, as well as female and male, faces that influence perception of age. In addition, they represent evidence of other-gender and other-race effects in age perception.

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56.325 **Does Observer's Ethnicity Affect Perceived Face Lightness? A Study of the Face-Lightness Distortion Effect for African American and Caucasian Observers** Nikolay Nichiporuk[1,2](nichiporuk@uchicago.edu), Kenneth Knoblauch[3], Clement Abbatecola[3], Steven K Shevell[1,2,4]; [1]Department of Psychology, University of Chicago, IL, USA, [2]Institute for Mind and Biology, University of Chicago, IL, USA, [3]University of Lyon, Universite Claude Bernard Lyon 1, INSERM, Stem Cell and Brain Research Institute, U1208, Lyon, France, [4]Department of Ophthalmology and Visual Science, University of Chicago, IL, USA

BACKGROUND The Face-Lightness Distortion Effect (FLDE) is an illusion causing African American faces to appear to be darker than Caucasian faces when matched for mean luminance and contrast (Levin & Banaji, 2006, J Exp Psychol Gen.; Nichiporuk et al., 2017 VSS). However, studies of the FLDE have predominantly used Caucasian participants, and an open question is the extent to which FLDE depends on the race of the observer. Here, the FLDE is measured using maximum likelihood conjoint measurement (MLCM) and for groups of African American and Caucasian observers. METHODS The joint influence of (1) overall mean luminance and (2) race of face on perceived face lightness was measured for 13 African American and 12 Caucasian observers. Thirteen African American faces ranging in mean luminance and contrast and 13 Caucasian faces, matched to the African American faces in mean luminance and contrast, were tested. Most pairs of 26 faces (either upright or inverted, in separate runs) were presented straddling fixation for 250 msec, followed immediately by a random noise mask (with replications, 1,800 judgments for each observer.) Perceptual lightness scales for all 26 stimuli were derived from MLCM. RESULTS & CONCLUSIONS Face race had a significant effect on perceived face lightness for the upright condition for 11 of 13 African American observers ($p < 0.01$), in the direction of a fixed decrement in face lightness for African American faces. The effect was significantly reduced for inverted compared to upright faces. For 12 out of 12 Caucasian observers, stimulus race also affected perceived face lightness ($p < 0.001$), again in the direction of a fixed decrement in face lightness for African American faces. Also, the effect was significantly reduced in the inverted compared to upright condition. Overall, the results show the FLDE is found for observers of both races.

56.326 **Is there more to a pretty face than it being one's "own-race"? Attractiveness ratings vary by skin tone, hair style, rater race and gender** Cheryl M Newsome[1], Briana N Cutliff[1], Brandy Hudson[1], Katherine R Torres[1], Alexander J Bies[1]; [1]Psychology, College of Behavioral and Health Sciences, Middle Tennessee State University

Most individuals choose own-race partners, an aspect of assortative mating, but studies of own-race biases in attractiveness have provided limited insights into the phenomenon. Previous research has shown no clear pattern of own-race preference in Caucasian and Asian individuals living in Asia or Australia. Here, we tested 1) whether prior results would generalize to a sample from the United States of America, and 2) the extent that cultural standards favoring straight hair (which lead many individuals, especially Blacks, to relax or straighten their hair) would impact attractiveness ratings. To perform the study, twenty photographs (4 sets of 5) of smiling women were selected from the internet and used to test whether skin (dark, light) and hair (straight, curly) would impact ratings of attractiveness. 113 participants who self-identified as "Black or African American" (39 female, 8 male) or "White or Caucasian" (53 female, 13 male) completed an online survey in which they were asked to rate attractiveness and other qualities of the women in the pictures. Picture order was randomized, and held constant across participants. A 4-way interaction was revealed with ANOVA. Black participants preferred dark skin and straight hair, then dark skin and curly hair, followed by light skin (regardless of hair). White women preferred straight over curly hair (regardless of skin), while white males exhibited preferences ordered from highest to lowest for light straight, light curly, dark straight, and finally dark curly. Excluding white females, there was an own-race bias, though the limited number of male participants included in the study makes it difficult to draw strong conclusions about own-race bias for partners. Cultural standards influence attractiveness in a consistent manner, as preference for straightened hair was observed in all groups. Malleable features, more than immutable attributes, may convey salient information that contributes to assortative mating in multicultural societies.

56.327 **The interaction between self-face, own-gender and left field biases in chimeric faces** Manuela Malaspina[1](m.malaspina1@campus.unimib.it), Roberta Daini[2,3], Jason JS Barton[1]; [1]Human Vision and Eye Movement Laboratory, Departments of Medicine (Neurology), Ophthalmology and Visual Sciences, Psychology, University of British Columbia, Vancouver, Canada, [2]Psychology Department, Università degli Studi di Milano-Bicocca, Milano, Italy, [3]COMiB – Optics and Optometry Research Center, Università degli Studi di Milano-Bicocca, Milano, Italy

Background: Judgments involving face perception have been reported to show some inherent biases, notably the self-face advantage and a preference for the halve of the face seen in the left hemifield. How these interact and whether these biases show the inversion effects that are the signature of face processing expertise is not known. Goal: We used whole and chimeric split-gender faces to study field bias, own-gender bias, and self-face bias to determine the relative magnitude of these effects in stimuli where these may interact. Methods: Twenty participants underwent a gender decision task with female/male chimeric faces, some of which used unknown faces of the same gender and some of which used the self-face, in both upright and inverted presentation. We measured participants' response bias in accuracy in the different conditions. Results: our control non-chimeric stimuli confirmed both a self-face advantage and an inversion effect for gender decisions. Gender decisions about non-self faces did not differ in accuracy. With our experimental chimeric stimuli, we found a robust left field bias for upright faces, which did not vary with whether self or non-self faces were used as the own gender face-half. Inverted faces did not show a significant field bias. The self-face advantage was equally strong in right and left face halves. There was an equally robust self-face bias for upright but not inverted faces. However the own-gender bias did not reach significance. Conclusion: Gender decisions by human observers show equally strong left-field and self-face biases, but not own-gender biases, and these appear to be independent effects. Like many other perceptual decisions about faces, these effects are specific to upright faces.

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56.328 **The big nose bias, or when distinctiveness hinders face learning: Evoking an other-race effect with selectively manipulated same-race faces** Jürgen M Kaufmann[1,2](juergen.kaufmann@uni-jena.de), Sandro Vogt[1,3], Stefan R Schweinberger[1,2]; [1]Department of General Psychology and Cognitive Neuroscience, Friedrich Schiller University of Jena, Germany, [2]DFG Research Unit Person Perception, Friedrich Schiller University of Jena, Germany, [3]Department of Psychology, Brock University, St. Catharines, Ontario, Canada

Although the other-race effect (ORE) is a very reliable finding, its underlying mechanisms are still under debate. This study is based on seemingly paradoxical findings in the face learning literature: While other-race faces and caricatures of same-race faces evoke very similar patterns of event-related potentials (smaller P200 and larger N250 components compared to veridical same-race faces), behavioural effects are exactly the opposite (better performance for caricatures, poorer performance for other-race faces). This could suggest qualitatively similar processes for both types of faces at learning, but with different consequences for recognition: When learning any unfamiliar face, deviations from the norm are used for forming a basic mental representation. Such distinctive information is useful in the case of caricatures, because the deviations from the norm are in different directions for each individual face, but misleading for other-race faces, because the most salient deviation from the norm is in the same direction for all members. We tested this idea by using highly

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distinctive same-race (Caucasian) faces with all noses manipulated in a uniform direction. In a learning/recognition task, we compared performance for these faces to veridical same- and other-race (Asian) faces. Our main aim was to simulate an ORE with the highly distinctive “big-nose” same-race faces. In accuracies and RTs, we found significant costs both for “big-nose” and other-race faces, compared to same-race veridicals. In ERPs, we observed a similar pattern for “big-nose” and other-race faces, with smaller P200, larger N250 and larger LPC compared to veridical same-race faces. Overall, our results support a perceptual account of the ORE. However, they suggest that qualitatively similar processes mediate the learning of unfamiliar same- and other-race faces, but with different consequences due to differences in the usefulness of the respective distinctive information.

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56.329 **Preference for attractive faces is species-specific** Fabrice Damon[1](damon.fabrice@gmail.com), Zhihan Li[2], Yin Yan[2], Wu Li[2], Kun Guo[3], Paul C Quinn[4], Olivier Pascalis[5,6], David Méary[5,6]; [1]Centre des Sciences du Goût et de l’Alimentation, AgroSup Dijon, CNRS, INRA, Université Bourgogne Franche-Comté, [2]State Key Laboratory of Cognitive Neuroscience and Learning and IDG/McGovern Institute for Brain Research, Beijing Normal University, [3]School of Psychology, University of Lincoln, [4]Department of Psychological and Brain Sciences, University of Delaware, [5]Univ. Grenoble Alpes, LPNC, [6]CNRS, LPNC

Biological accounts of facial attractiveness have typically presented preferences for attractive faces as arising from adaptations for mate choice or as by-products of general sensory bias (Little et al., 2011; Rhodes, 2006). Both frameworks place the mechanisms responsible for the preferences for attractive faces in the evolution of the human lineage, leaving open the possibility that non-human primates might also share such mechanisms, and therefore show a form of sensitivity to attractive faces. If human ratings of attractiveness are the product of mechanisms shared among primates, they might also predict visual face preferences in monkeys. We sought to determine whether explicit ratings of attractiveness by human judges would predict implicit visual preferences in other humans and also in non-human primates, and if they do, whether such preferences would extend beyond conspecific faces. Human and rhesus macaque faces were rated for attractiveness by human judges, and paired in accord with the attractiveness ratings (i.e., attractive faces paired with unattractive faces). Face pairs were shown to human and rhesus macaque participants while their eye-movements were recorded. We found that human ratings of attractiveness predicted implicit preferences in non-human primates. However, we also found a species-specific effect of face attractiveness in which humans showed a visual preference for human faces (but not macaque faces) rated as attractive, and macaques displayed a visual preference for macaque faces (but not human faces) rated as attractive (Figure 1). The findings suggest that attentional bias toward attractive faces is not the result of an exclusive operation of mate choice adaptation mechanisms, nor a reflection of the sole influence of a general sensory bias, but rather it reflects their interaction. The influence of a general sensory bias may be modulated by the categorization of a face as conspecific or heterospecific, leading to species-specific preference for attractive faces.

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56.330 **Cultural differences in spatial frequency utilisation do not generalize across various object classes** Caroline Blais[1](caroline.blais@uqo.ca), Amanda Estéphan[1,2], Michael N’Guiamba N’Zie[1], Marie-Pier Plouffe-Demers[1], Ye Zhang[3,4], Dan Sun[3,4], Daniel Fiset[1]; [1]Psychology department, University of Quebec in Outaouais, [2]Psychology department, University of Quebec in Montreal, [3]Institute of Psychological Sciences, Hangzhou Normal University, [4]Zhejiang Key Laboratory for Research in Assessment of Cognitive Impairments

Several studies have shown cultural differences in the fixation patterns observed during tasks of different nature, e.g. face identification (Blais et al., 2008; Kelly et al., 2011), race categorization (Blais et al., 2008), and recognition of visually homogeneous objects (Kelly et al., 2010). These differences suggest that Easterners deploy their attention more broadly and rely more on extrafoveal processing than Westerners (Miellet et al., 2013). This finding is in line with a dominant theory in the field suggesting that cultural differences in cognition, attention and perception may be related to social systems (Nisbett & Miyamoto, 2005). Specifically, Easterners, because they have evolved in a more collectivistic system, would deploy their attention more broadly than Westerners, who have evolved in a more individualistic system. However, studies revealing cultural differences in fixation patterns during face processing have been challenged by the findings that two fixations suffice for face recognition (Hsiao & Cottrell, 2008), and that early fixations are not modulated by culture (Or, Peterson & Eckstein, 2015). Since deploying attention over a broader area has been shown to modulate the spatial resolution, directly assessing the spatial frequency (SF) utilisation underlying stimulus recognition would help clarify the impact of culture on perceptual processing. Here, we present a set of four experiments in which the SF used by Easterners and Westerners were measured while they identified faces, discriminated familiar from unfamiliar faces, and categorized object and scenes. The results reveal that Easterners are tuned towards lower SF than Westerners when they identify faces and discriminate familiar from unfamiliar ones (Tardif et al., 2017), but use the same SF to categorize objects and scenes. Together, these results challenge the view that the exposition to different social systems leads to the development of different perceptual strategies generalizable to various object classes.

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56.331 **Examining cultural differences in naturalistic face scanning: A data-driven approach to analysing head-mounted eye-tracking data** Jennifer X Haensel[1](jhaens01@mail.bbk.ac.uk), Matthew Danvers[1], Mitsuhiko Ishikawa[2], Shoji Itakura[2], Tim J Smith[1], Atsushi Senju[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, [2]Department of Psychology, Kyoto University

Recent eye-tracking studies have demonstrated significant differences in face scanning strategies between Western Caucasians (WC) and East Asians (EA), challenging the notion of universality in face perception. However, previous studies have been restricted to screen-based paradigms, which lack the visual complexity and social presence of real-world conditions. The current study therefore used head-mounted eye-tracking techniques to investigate cultural differences in naturalistic face scanning behaviour. Thirty British and 27 Japanese adults introduced themselves and played a story-telling game with a local confederate (in the UK or Japan) while their eye movements were recorded. We developed semi-automatic MatLab tools that can dynamically track regions of interest (upper/lower face) and classify gaze points accordingly. Results showed that both EA and WC groups looked significantly more at the face when listening compared to speaking. Cultural differences were observed for speaking periods, with WC individuals showing more face gaze at the listening partner. A tendency for increased gaze scanning (proportional to face looking time) was found for the EA group, challenging reports of gaze avoidance in EA observers (Argyle et al., 1986). To employ a more spatially-sensitive and data-driven approach, we mapped face regions and gaze points into a normalised space to generate z-scored difference maps of gaze density. Initial results showed that EA participants exhibited more localised face scanning, with increased gaze at the nose and between the eyes of the conversational partner. WC observers, meanwhile, showed greater gaze distribution and looked more at the mouth region. Overall, this study introduced semi-automatic and data-driven approaches for analysing data from head-mounted eye-trackers, with findings demonstrating cultural differences in face scanning under naturalistic conditions for the first time.

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56.332 **Strategies for improving own-and other-race face recognition with learning context and multiple image training** Jacqueline G Cavazos[1](jacqueline.cavazos@utdallas.edu), Eilidh Noyes[1], Alice J O’Toole[1]; [1]School of Behavioral and Brain Sciences, The University of Texas at Dallas

The Other-Race Effect (ORE) refers to the well-known finding that people recognize own-race faces more accurately than other-race faces. Is it possible to reduce the ORE? Here, we examined the role of learning context, in combination with multiple-image training on recognition accu-

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racy for own-and other-race faces. East Asian and Caucasian participants saw images of each identity in either a contiguous order (multiple images of an identity grouped together) or a distributed order (multiple images of an identity dispersed randomly throughout the learning set). Participants learned faces from four highly variable images (Exp. 1A) or from one image repeated four times (Exp. 1B). A robust other-race effect was found in both experiments, indicating that image variability alone is insufficient to eliminate the other-race effect. Also, the effect of learning context was mediated by image variability. Participants in the distributed learning condition were more accurate when they trained with a single repeated image (Exp. 1B), $F(1,136) = 5.633$, $MSE = 0.60$, $p = .019$, $\eta p2 = .04$, but not from multiple variable images (Exp. 1A), $F(1,129) = 0.140$, $MSE = 0.49$, $p = .71$, ns. Overall, accuracy was higher for multiple image training ($M = 1.22$, $SD = 0.49$) than repeated single image training ($M = 1.01$, $SD = 0.56$), $F(1, 265) = 10.712$, $MSE = 0.55$, $p = .001$, $\eta p2 = .039$. Our novel approach revealed that a distributed learning context improves own-and other-race recognition accuracy, but only when participants can already "tell faces together" (Jenkins et al., 2011). Also, using a cross-race experiment, we extended previous results that suggest that multi-image training improves recognition accuracy for own-race (Murphy et al., 2015) and other-race faces (cf., Matthews and Mondloch, in press). Our results indicate that, with lower image variability, distributed learning can improve recognition accuracy for both own-and other-race faces.

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56.333 **Cross-Cultural and Cultural-Specific Visual Perception of Facial Expressions of Emotion in the Wild** Ramprakash Srinivasan[1](srinivasan.134@osu.edu), Aleix M Martinez[1]; [1]Electrical and Computer Engineering, The Ohio State University

Although there is agreement that facial expressions are a primary means of social communication amongst people, which facial configurations are successfully visually interpreted within and across cultures is a topic of intense debate that has reached an impasse. This impasse can only be addressed once we know which facial expressions are successfully visually interpreted within and across cultures in the wild, not in controlled lab conditions. Yet, no such studies exist. We present the first large-scale study of the visual perception of facial expressions of emotion in the wild. Specifically, we analyze over 7 million images. We find that of the 16,384 possible facial configurations that people can produce, only 35 are successfully employed to transmit emotive information across cultures, and only 8 within a small number of cultures. Crucially, we find that the visual analysis of these 35 cross-cultural expressions yields consistent visual perception of emotion categories and valence, but not arousal. In contrast, visual analysis of the 8 cultural-specific expressions yields consistent perception of valence and arousal, but not of emotion categories. In addition, we find that the number of facial configurations that are visually interpreted as communicating each emotion category varies significantly. At one extreme, happiness is visually perceived in seventeen facial configurations. At the other end, disgust is only visually identified in a single expression. We also find that the degree of successful visual interpretation of these facial expressions varies significantly. These unexpected results cannot be explained by current models of the perception of facial expressions.

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56.334 **The impact of culture on visual strategies underlying the judgment of facial expressions of pain.** Camille Saumure[1](sauc14@uqo.ca), Marie-Pier Plouffe-Demers[1], Daniel Fiset[1], Stéphanie Cormier[1], Dan Sun[3,4], Zhang Ye[3,4], Miriam Kunz[2], Caroline Blais[1]; [1]Département de psychoéducation et de psychologie, Université du Québec en Outaouais, [2]Department of General Practice and Elderly Care Medicine, University of Groningen, [3]Institute of Psychological Sciences, Hangzhou Normal University, [4]Zhejiang Key Laboratory for Research in Assessment of Cognitive Impairments

Research has revealed that observers' ability to recognize basic facial emotions expressed by individuals of another ethnic group is poor (Elfenbein, & Ambady, 2002), and that culture modulates the visual strategies underlying the recognition of basic facial expressions (Jack et al., 2009; Jack, Caldara, Schyns, 2012; Jack et al., 2012). Although it has been suggested that pain expression has evolved in order to be easily detected (Williams, 2002), the impact of culture on the visual strategies underlying the recognition of pain facial expressions remains underexplored. In this experiment, Canadians (N=28) and Chinese (N=30) participants were tested with the Bubbles method (Gosselin & Schyns, 2001) to compare the facial features used to discriminate between two pain intensities. Stimuli consisted of 16 face avatars (2 identities x 2 ethnicities x 4 levels of intensity difference) created with FACEGen and FACSGen. The amount of facial information needed to reach an accuracy rate of 75% was higher for Chinese ($M=93.3$, $SD=25.04$) than for Canadian participants ($M=47.2$, $SD=48.02$) [$t(44.3)=-4.63$, $p< 0.001$], suggesting that it was harder for Chinese to discriminate among two pain intensities. Classification images representing the facial features used by participants were generated separately for Asian and Caucasian faces. Statistical thresholds were found using the cluster test from Stat4CI (Chauvin et al, 2005; $Zcrit=3.0$; $k=667$; $p< 0.05$). Canadians used the eyes, the wrinkles between the eyebrows and the nose wrinkles/upper lip area with both face ethnicities. Chinese used the eye area with Asian faces, but no facial area reached significance with Caucasian faces. Compared with Chinese participants, Canadians relied more on the nose wrinkles area ($Zcrit=3.0$; $k=824$; $p< 0.025$). Together, these results suggest that culture impacts the visual decoding of pain facial expressions

Acknowledgement: Social Sciences and Humanities Research Council

56.335 **The impact of culture on the visual representation of pain facial expressions** Marie-Pier Plouffe Demers [1](plom09@uqo.ca), Camille Saumure[1], Stéphanie Cormier[1], Daniel Fiset[1], Miriam Kunz[2], Dan Sun[3,4], Zhang Ye[3,4], Caroline Blais[1]; [1]Department of psychoeducation and psychology, Université du Québec en Outaouais, [2]Department of General Practice and Elderly Care Medicine, University of Groningen, [3]Institute of Psychological Sciences, Hangzhou Normal University, [4]Zhejiang Key Laboratory for Research in Assessment of Cognitive Impairments

Some studies suggest that communication of pain is connected to the evolution of human race and has evolved in a way to increase an individual's chance of survival (Williams, 2002). However, even though facial expressions of emotions have long been considered culturally universal (Izard, 1994; Matsumoto & Willingham, 2009), some studies revealed cultural differences in the perceptual mechanisms underlying their recognition (e.g. Jack et al., 2009; Jack et al., 2012). The present study aims to verify the impact of culture on the facial features that are stored by individuals in their mental representation of pain facial expressions. In that respect, observer-specific mental representations of 60 participants (i.e. 30 Caucasians, 30 Chineses) have been measured using the Reverse Correlation method (Mangini & Biederman, 2004). In 500 trials, participants chose, from two stimuli, the face that looked the most in pain. For each trial, both stimuli would consist of the same base face (i.e. morph between average Asian and Caucasian avatars showing low pain level) with random noise superimposed, one with a random noise pattern added, and the other the same pattern subtracted. We generated a classification image (CI) for each group by averaging noise patterns chosen by participants. The cultural impact on mental representations was measured by subtracting the Caucasian CI from the Chinese CI, to which was applied a Stat4CI cluster test (Chauvin et al., 2005). Results indicate significant differences in the mouth and left eyebrow areas ($ZCrit=3.09$, $K=167$, $p< 0.025$), and suggest a mental representation of pain facial expression of greater intensity for Chinese participants. Given that mental representations reflect expectations about the world based on past experiences (Jack et al., 2012), the results suggest that Chinese participants may have previously been exposed to facial expressions displaying greater pain intensities.

Acknowledgement: Social Sciences and Humanities Research Council

Attention: Inattention and attentional blink

Tuesday, May 22, 2:45 - 6:45 pm, Banyan Breezeway

56.336 **Do we understand the paradoxical effect of attention on visual adaptation?** Jan Brascamp[1,2](brascamp@msu.edu), Cheng Stella Qian[1], Alexis Mareschi[1]; [1]Department of Psychology, College of Social Science, Michigan State University, [2]Neuroscience Program, Michigan State University

Withdrawing attention from an image can paradoxically make its subsequent negative afterimage more vivid. Existing literature (e.g. Suzuki & Grabowecky, 2003, JEP:HPP 29(4)) suggests the following explanation: besides causing an afterimage, adaptation also reduces visual sensitivity, and withdrawing attention from an adapter may primarily act to minimize this sensitivity reduction. The enhanced vividness, under this account, would thus reflect higher sensitivity. A cartoon that illustrates this explanation is one in which afterimages arise early (say, subcortically), but are 'viewed' by the observer through a later channel, whose sensitivity is affected during adaptation. Here we investigated whether the paradoxical effect of attention also occurs for other visual adaptation phenomena, namely the tilt aftereffect and the motion aftereffect. We were particularly motivated by the consideration that the above cartoon, although roughly appropriate for afterimages, does not obviously generalize to those phenomena, suggesting neither does the paradoxical effect. We applied the same attention manipulation in three conditions involving afterimages, tilt aftereffects and motion aftereffects, respectively. In each case we varied the strength of a nuller stimulus to construct psychometric curves, plotting the proportion of trials where the nuller outweighed the aftereffect as a function of this strength. The mean of such a curve indicates aftereffect strength (i.e. the amount of nulling needed to cancel it), whereas the slope indexes sensitivity. To our surprise, we obtained similar results for all conditions: withdrawing attention from the adapting display resulted in a lower mean, indicating a weaker aftereffect, but also in a steeper slope, indicating superior sensitivity. Our results suggest that a situation as sketched in our cartoon also applies to tilt aftereffects and motion aftereffects. They furthermore imply that the paradoxical effect of inattention, enhanced aftereffect vividness, can also arise for those aftereffects, namely in situations where the superior visual sensitivity outweighs the weakened aftereffect.

56.337 **Perceptual similarity and working memory load in visual search for multiple targets** Elena S Gorbunova[1](gorbunovaes@gmail.com), Kirill S Kozlov[1]; [1]National Research University Higher School of Economics

Subsequent search misses (SSM) refer to the decrease in accuracy at detecting a second target after a first target has been found (Adamo et al., 2013). Two major explanations of this phenomenon assume perceptual bias and working memory overload created by the first target processing. Two experiments were conducted to reveal the interaction between the factors of perceptual similarity and working memory load. The participant's task was to search for the targets - rectangles with gaps on one predetermined side among distractors - rectangles with gaps on the other sides. On each trial, in could be two, one or no targets. Perceptual similarity for dual-target trials was manipulated as the number of shared features (color and size) in two targets. Working memory load was manipulated with the additional memorization task. The first experiment assumed memorizing the irrelevant shapes, whereas the second assumed memorizing the rectangles similar to visual search task stimuli. Three conditions were used: visual search alone (VS), working memory alone (WM) and combined visual search and working memory condition. In the VS task, the participants had to search for targets among distracters. In WM task, the participants performed a modified change-detection task with shape as the relevant feature: the shapes of the objects were displayed, then it was the retention interval, after which the shapes were displayed again and the subjects had to report if the shapes were equal to the initial ones or not. In the combined task, the participants had to memorize the shapes, conduct the VS task and then give the response to WM task. The visual search task and working memory task accuracy for each condition were compared. The results revealed the interaction between working memory load and perceptual similarity factors. Based on this data, we propose the integrative explanation of SSM errors.

56.338 **The attentional blink and repetition blindness redux: Testing the perceptual wink model** Lucas Huszar[1](lukehuszar@gmail.com), David E Huber[1]; [1]Department of Psychological and Brain Sciences, University of Massachusetts, Amherst

Chun (1997) examined repetition blindness (RB) within a letter-number attentional blink (AB) paradigm. Supporting the conclusion that the AB and RB reflect different mechanisms, he found that some manipulations selectively reduced the AB while others selectively reduced the RB. This conclusion appears to contradict the recently proposed 'perceptual wink' model of Rusconi and Huber (2017). On this account, both the AB and RB reflect perceptual habituation: RB is habituation for a character's identity (i.e., which letter or number), whereas the AB is habituation for the category of the character (i.e., a failure to perceive that the second target belonged to the target category). Because different representations underlie each effect, the same mechanism of perceptual habituation can explain the dissociation reported by Chun. To test this account, we ran a series of three experiments, manipulating the degree to which targets were readily identified as belonging to the target category. Each experiment used a between-subjects manipulation in which one group received consistent mapping (CM), with a set of characters consistently assigned to the target category across trials, whereas the other group received varied mapping (VM) by varying the assignment of characters to the target category versus the distractor category. All experiments examined the AB and RB simultaneously, but unlike Chun, these experiments used multiple choice testing to assess any strategy or bias present in the decision process. Across all three experiments, VM produced weaker AB effects as compared to CM. Numerically, RB was also weakened by the CM/VM manipulation, as expected if the loading of a character's identity into working memory requires both identifying a character (the RB) and recognizing it as being a target (the AB). The results of all three experiments were well accounted for by the perceptual wink model using the same habituation parameters.

56.339 **Confidence blinks before attention** Samuel Recht[1](samuel.recht@ens.fr), Pascal Mamassian[1], Vincent de Gardelle[2]; [1]Laboratoire des Systèmes Perceptifs, École Normale Supérieure — PSL Research University, Paris, France, [2]Centre d'Economie de la Sorbonne, CNRS UMR 8174, Paris, France, Paris School of Economics, Paris, France

How does confidence track temporal attention? Visual confidence is a second order estimation of a primary decision and could be assimilated to the subjective probability of being correct in a task. Metacognitive sensitivity concerns the variance in accuracy that confidence could account for, after controlling for bias. Temporal attention has been studied through the "Attentional Blink" (AB) phenomenon: when two targets (T1 and T2) are displayed too close in time in a RSVP stream, the second target is often missed. This effect is most pronounced for the second and third items after T1 in the stream. Yet, when T2 is presented just after T1, the AB is not present – an effect called "lag-1 sparing". Here, we ask whether observers are metacognitively aware of such non-monotonous fluctuations of their performance during the AB. To do so, we engaged participants (N=34) in a RSVP identification task: they had to report two target letters in a stream, and then evaluate their confidence about these reported letters. Discrimination accuracy replicated the AB and Lag-1 sparing phenomena. Confidence about T2, however, was dissociated from accuracy: confidence was comparable for Lag-1 and Lag-2, while accuracy was much greater at Lag-1. To distinguish between metacognitive bias and metacognitive sensitivity, the distribution of errors around T2 during Lag-1 was analysed. Despite the strong under-confidence, participants' confidence still discriminated between large and small temporal selection errors. However, comparing Lag-1 to Lag-6 that showed similar accuracy levels, metacognitive sensitivity was reduced for Lag-1, suggesting that only part of the confidence evidence was preserved at Lag-1. At the peak of the AB, in the near-absence of attention (Lag-2), metacognitive sensitivity was nearly absent. These results suggest that confidence blink, which seems mainly due to metacognitive bias, has a temporal structure that is distinct from both temporal attention and metacognitive sensitivity.

56.340 **iBlindness: Restoring Situational Awareness to Pedestrians Using Smartphones** Joshua James New[1](jnew@barnard.edu), Nechama Kaiser[1]; [1]Department of Psychology, Barnard College, Columbia University

 See page 3 for Abstract Numbering System

Smartphones have been implicated in the rapid increase of pedestrian injuries and deaths: not only by distracting drivers, but also pedestrians who are using (e.g. texting) and/or listening to smartphones (e.g. headphones) around traffic. These studies are part of a project developing technology for detecting oncoming vehicles and alerting distracted walkers. We used a spatial cuing task to evaluate 1) how deleterious smartphone use is to observers' awareness of surrounding events, and 2) the extent that auditory alerts could speed distracted observers' reactions to appearing hazards. Seated observers were asked to respond as quickly as possible where a target (8.7° x 0.6° black vertical bar) appeared. These targets were projected at their approximate eyeline on the wall in front of them, and moved horizontally from the projected display's right or left edge to its midline, or until the participant responded by depressing their right or left footpedal. In the baseline experiment, participants used their silenced smartphones freely in every other trial block, and performed only the detection task in the other blocks. As expected, when using their smartphones, participants were significantly slower to detect appearing targets. This increased latency, however, was virtually eliminated when targets were accompanied by an alerting, nondirectional tone – as this technology could provide. In Experiment 2, participants performed the same task but used their smartphones in every block. Again, targets were reported significantly more quickly when accompanied by a nondirectional tone. Unexpectedly, valid directional alerts – tones from a speaker on their left or right – were no more effective at speeding target detection than nondirectional alerts, and verbal alerts ("LEFT", "RIGHT") were significantly less effective. These results were replicated in Experiment 3, but slowed overall by having participants respond in the opposite direction of the target – as one might to avoid a hazard.

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56.341 Kanizsa-figure object completion determines attentional selection in time: Evidence from the attentional blink

Markus Conci[1](conci@psy.lmu.de), Qi-Yang Nie[1], Hermann J. Müller[1], Siyi Chen[1]; [1]Department of Psychology, Ludwig-Maximilians-University Munich, Germany

Previous work has demonstrated that perceptual grouping modulates the selectivity of attention across space. However, how grouping influences the allocation of attention over time is much less clear. The current study investigated this issue, using an attentional blink (AB) paradigm with Kanizsa figure configurations that systematically varied the strength of grouping, thus permitting the effects of object integration upon initial selection and subsequent short-term memory consolidation of a target to be determined. On a given trial, two red Kanizsa-type targets (T1, T2) were embedded in a rapid serial visual presentation stream of irrelevant distractors. We observed the typical AB phenomenon: impaired identification of T2 when presented close in time after T1. Moreover, the AB was modulated by T2 grouping, with stronger grouping resulting in a reduced AB and higher performance overall. This influence of grouping was independent of the perceptual organization of T1 (grouped or ungrouped). By contrast, an opposite pattern – of an increased AB with increasing grouping strength – was obtained when the Kanizsa figure was not task-relevant. Together, these findings suggest that the grouping benefit emerges at early perceptual stages, automatically drawing attentional resources, thereby leading to either sustained benefits or transient costs – depending on the task-relevance of the grouped object. This indicates that grouping modulates processing of objects in time.

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56.342 Expectation Blindness: Seeing a face when there is none.

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

Inattentional blindness (IB) is the failure to see an unexpected stimulus under conditions of inattention. Here we describe a correlative phenomenon, expectation blindness: blindness to the absence of an expected stimulus. Previously we described an experiment in which 80% of observers reported an absent, expected, simple stimulus (a colored circle) as present (Erol et al., 2016). This also was true when the expected stimulus was a letter matrix (Mack et al., 2015). The current study demonstrates the same phenomenon with a highly salient stimulus, which is resistant to IB (Mack & Rock, 1998) and might be resistant to expectation blindness. Using an IB procedure with 16 trials in the inattention, 5 in the divided and 4 in the full attention condition in which a face was present at fixation, 15 Os reported whether 4 color bisected circles surrounding the face were the same or one was different. On the 3 critical trials, the last trial in each condition, the face was absent, while for 15 control Os it was present. After reporting the circles, Os were immediately asked whether they had seen anything other than the circles. When the face was absent, 73.3% reported seeing a face in the inattention, 46.7% in the divided, and 0% in the full attention condition. When the face was present, 66.7% reported seeing it in the inattention condition, 93.3% with divided and 100% with full attention. When the face was absent, there was a significant decrease in the frequency of reporting a face as attention to the location of the face increased ($\chi2(2)=16.909$, $p = .000$). The reverse was true when the face was present ($\chi2(2)=7.000$, $p = .030$). These results demonstrate the enormous power of an incidentally developed expectation, which is strong enough to cause us to see a face in its absence.

56.343 The Power of Hypnosis to Reduce the Attentional Blink.

Oksana Freedman[1](freeo449@newschool.edu), Arien Mack[1]; [1]The New School University

When two targets are presented in a RSVP stream of visual stimuli, the second target is likely to be missed if it occurs between 200ms and 500ms after the first. This is the Attentional Blink (AB). We explored whether post-hypnotic suggestion can reduce the AB when it directs attention exclusively to the targets. We compared the AB in 12 highly hypnotizable participants (group 1) to 10 less hypnotizable Ps (group 2) and 10 control Ps (group 3). Group 1 and 2 received a post hypnotic suggestion to attend only to numbers in the RSVP stream (17-19 letters and 2 numbers) between two sets of 60 trials, while group 3 did the same tasks with no suggestion. In the two groups receiving post hypnotic suggestion hypnosis was induced using a modified Elman's hypnotic technique (Elman, 1970). All three groups showed an equivalent AB in the first set of trials. Importantly, we found that group 1 showed a significantly smaller AB in the second set of trials than in the first (p=.018) and a significantly smaller AB relative to groups 2 and 3 who showed no reduction in AB in the second set. The AB analysis revealed main effect for suggestion ($F(1,22) = 5.413$, $p = .012$). This demonstrates the power of hypnosis to unconsciously amplify the attentional filter, making it more selective so that it can more successfully gate out irrelevant information.

56.344 Attenuation of Inattentional Blindness in Individuals who are HIV Positive

Maegen Walker[1](maegenw@hawaii.edu), Cecilia Shikuma[2], Scott Sinnett[1]; [1]Psychology, University of Hawaii at Manoa, [2]Medicine, John A. Burns School of Medicine, University of Hawaii

Inattentional blindness (IB) is categorized as the inability to perceive stimuli or events, sometimes salient and highly visible, due to a lack of attention. This perceptual failing serves a functional purpose allowing attentional resources to be focused on a current task by filtering (i.e., inhibiting) task-irrelevant visual information. IB has been well documented and replicated in a variety of laboratory and naturalistic settings. However, the extent to which IB is modulated by brain injury or disease is relatively understudied. The human immunodeficiency virus (HIV) is known to disrupt attentional processes leading to higher rates of distractibility. Due to this documented attentional deficit, we predicted that people who are HIV positive (+) might be less likely to experience IB for highly salient, unattended, stimuli. Therefore, we expected that individuals who are HIV+ would exhibit improved perception of task irrelevant items compared to those who are HIV negative (-). We investigated this hypothesis by comparing performance on a well-established IB paradigm between individuals who are HIV+ and an age matched HIV- control group. Participants were presented with a rapid stream of pictures superimposed with written words. They were asked to identify immediate picture repetitions (i.e., targets) while ignoring the superimposed words (Figure 1). Replicating the robust literature on IB, and despite the unattended words being plainly visible, all participants had difficulty identifying these items in a subsequently presented surprise recognition task. Importantly, the HIV- control group exhibited significantly higher rates of IB, recognizing only 29% of the unattended words, compared to the participants with HIV who recognized 52% of these items (Figure 2). These data suggest that attentional deficits associated with HIV may also contribute to an attenuation of inattentional blindness among this patient population.

Attention: Individual differences

Tuesday, May 22, 2:45 - 6:45 pm, Banyan Breezeway

56.345 Distinct correlates of perceptual capacity and working memory capacity in brain structure and behaviour

Joshua O Eayrs[1](Joshua.Eayrs.13@ucl.ac.uk), Nilli Lavie[1]; [1]Institute of Cognitive Neuroscience, University College London

The Load Theory of attention and cognitive control (e.g. Lavie et al, 2004) proposes a dissociation between limited capacities for perception and working memory control. Previous support rested on experimental demonstrations of opposite effects of perceptual load and working memory load on distractor perception (Lavie, 2005 for review). Here we apply an individual differences approach to both task performance and brain structure, dissociating perceptual capacity from working memory capacity across different attention-demanding tasks. Task performance measures in change detection, multiple object tracking (MOT), subitizing (the ability to detect small numbers of items in parallel from a rapid presentation) and three complex span working memory tasks were assessed for 112 participants. Factor analyses supported a two-factor model in which distinct sources of common variance were found in change detection, MOT and subitizing in one factor and working memory performance in another. Structural MRI scans were obtained for 44 participants from this sample. Voxel-Based Morphometry (VBM) analysis indicated a common region of grey matter density in the right Tempo-ro-Parietal Junction (rTPJ) associated with perceptual capacity: higher grey matter density in rTPJ was found for individuals with higher perceptual capacity across change detection, MOT and subitizing. In contrast; higher working memory capacity was associated with greater grey matter density in the left middle frontal gyrus. Furthermore, the correlates of perceptual capacity remained significant when controlling for variance accounted for by working memory capacity, and vice versa. These results provide a new line of support for the Load Theory proposal of dissociable perceptual and working memory control capacities. The association of these functions with differences in the grey matter density of parietal and frontal cortex respectively suggests that they represent a lasting individual attribute.

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56.346 Pupillometry as a window into the content and strength of attention sets

Nelson A Roque[1](roque@psy.fsu.edu), Walter R Boot[1]; [1]Psychology Department, College of Arts & Sciences, Florida State University

Research has highlighted the potential of pupil size as a measure of the allocation of attention (Mathôt, van der Linden, Grainger, & Vitu, 2013), with pupil size also observed to reflexively respond to words that convey a sense of lightness or darkness (Mathôt, van der Linden, & Strijkers, 2017). If pupillary response is sensitive to mental representations associated with lightness/darkness, can pupil size serve as an observable measure of an individual's attention set during search? Further, if maintaining an attention set for a white target has a different effect on pupillary response compared to maintaining an attention set for a black target, can the size of this difference index the strength of an individual's attention set? If so, pupil response preceding target presentation should be predictive of task accuracy. Our experiment asked participants to search an RSVP stream of gray letters, and report the identity of a black or white letter. At the beginning of each trial, participants were cued to their target of search (report white or black letter) by either a visual or auditory cue (cue type was blocked and counterbalanced). Overall accuracies across cue presentation method were not significantly different ($t(42) = 1.20$; $p = 0.24$), so pupillometry measures were collapsed across cue type. Preceding the target presentation pupillary response curves for black and white target trials were created for each participant, with metrics including a difference score derived from these curves, and the maximal difference between the two functions. The maximal difference between both curves (representing attentional set modulation) was correlated with task accuracy ($r = 0.23$; $p = 0.053$), whereas the point at which the maximal difference occurred was not significantly correlated with overall accuracy ($r = -0.02$; $p = .897$). These data highlight the predictive potential of pupillometry measures to determine both the content and strength of an observer's attention set.

Acknowledgement: NA

56.347 Enhanced visual attention in university hockey players

Kait Clark[1,2](kait.clark@uwe.ac.uk), Michael Maddocks[2]; [1]Department of Health and Social Sciences, University of the West of England, [2]School of Psychology, Cardiff University

Elite athletes exhibit enhanced cognitive abilities related to sport, and athletes' perceptual-cognitive expertise may also transfer to computer-based cognitive tasks in the laboratory (see Voss et al., 2010 for a meta-analysis). The research in this area, however, is notoriously under-powered, often relying upon small sample sizes and producing results that fail to meet statistical significance. One recent study attempted to overcome these limitations by testing a large number of volleyball players on a range of cognitive tasks (Alves et al., 2013), but only small effects were observed, and the tasks employed did not sample the full range of visual-attentional skills. Because athletic training protocols can potentially enhance some aspects of attention but not others (e.g., Appelbaum et al., 2011), we aimed to assess whether superior performance among athletes would be observed when tested on a wider range of perceptual and attention skills. We conducted a comprehensive battery of computer-based visual tasks and compared performance between Cardiff University hockey players and non-athlete student controls. Our measures allowed for a broad assessment of a range of attentional and perceptual skills, including selective attention (flanker compatibility task), sustained dynamic attention (multiple-object tracking task), and spatial distribution of attention (useful field of view task). We found that hockey players demonstrated enhanced performance in measures of selective attention and in identifying transient stimuli at central fixation. Importantly, these perceptual enhancements are apparent after controlling for potential group differences in motivation and strategy. Our results provide novel insight into the potential transferability of athletic training to perceptual skills and have implications for generalised enhancements in cognitive performance.

56.348 Evidence for a broader allocation of attention in emmetropes over myopes during three visual processing tasks

Amanda Estéphan[1,2](aesthellophane@gmail.com), Carine Charbonneau[1], Hana Furumoto-Deshaies[1], Marie-Pier Plouffe-Demers[1], Daniel Fiset[1], Roberto Caldara[3], Caroline Blais[1]; [1]Département de Psychoéducation et Psychologie, Université du Québec en Outaouais, [2]Département de Psychologie, Université du Québec à Montréal, [3]Department of Psychology, University of Fribourg

Last year (VSS, 2017), we explored the impact of myopia on visual attention as a possible explanation for the perceptual differences observed between Easterners and Westerners: namely, that Easterners have a larger global advantage than Westerners in a Navon Task (McKone et al., 2010); fixate less the eyes and mouth, and more the centre of the face during its processing (Blais et al., 2008); and tend to process faces in lower spatial frequencies (Tardif et al., 2017). Myopes and emmetropes were tested using Navon's paradigm to measure their ability to detect global versus local target letters, and the Spatial Frequency (SF) Bubbles method (Willenbockel et al., 2010a) to measure their use of SFs during a face identification task: we initially found unexpected results suggesting that emmetropes were better than myopes at detecting global letters and that they used lower SFs than the latter group to correctly identity faces. Here, we delved deeper into this inquiry: a greater number of participants were tested with Navon's paradigm (myopes = 18; emmetropes = 29) and with SF Bubbles (myopes = 15; emmetropes = 18). In addition, we measured participants eye-movements during another face recognition task (myopes = 11; emmetropes = 9). In support of our previous findings, our new results indicate that emmetropes have a higher global processing bias than myopes [$t(45) = -3.269$; $p = 0.002$], and make greater use of lower SFs, between 4.3 to 5.7 cycles per face [Stat4CI (Chauvin et al., 2005): $Zcrit=-3.196$, $p< 0.025$]. Finally, our eye-movement results suggest that emmetropes fixate the center of the face to a greater extent than myopes [analysis with iMap4 (Lao et al., in press)]. These findings offer a new avenue to explore how myopes and emmetropes process information contained in visual stimuli.

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56.349 **Heterogeneous cognitive profiles among children with Attention Deficit/Hyperactivity Disorder (ADHD)** Inbar L Trinczer[1,2](inbartrincher@gmail.com), Lilach Shalev[1,2]; [1]School of Education, Tel-Aviv University, [2]Sagol-School of Neuroscience, Tel-Aviv University

ADHD is a chronic mental health condition defined by behavioral symptoms of inattention, hyperactivity and impulsivity. Such definition completely ignores the cognitive deficits underlying ADHD. Moreover, ADHD symptoms (e.g. 'is easily distracted', 'cannot wait for his/her turn') are not exclusive to ADHD and may be present in various conditions. In order to better understand the diverse cognitive profiles among children with ADHD, our study examined approximately 80 children, 8-12 years-old, diagnosed with ADHD by a qualified clinician. Based on previous studies that focused on impaired cognitive mechanisms in ADHD, the following cognitive tests were administered: (1) Continuous Performance Test (CPT) to assess sustained attention; (2) conjunctive visual search task to assess selective-spatial attention; (3) spatial precueing task to assess orienting of attention; (4) spatial Stroop-like task to assess executive attention; (5) Wechsler's digit span forward and backward to assess the phonological loop and the central executive (CE) components of the Working Memory (WM) system, respectively; and (6) Corsi-Block task forward and backward to assess the visual-spatial sketchpad and the CE components of the WM, respectively. Based on data of age-matched typically developing (TD) children, collected in our lab in previous studies, we classified the performance of each participant on each cognitive task as either impaired (lower 10% of TD children) or intact. Various frequencies of impairments were obtained in different cognitive functions, ranging from 17% in selective-spatial attention, up to 56% in sustained attention. While a substantial sub-group of participants showed impairment in more than one cognitive function, another sub-group of participants demonstrated intact performance on all the above cognitive tasks. Our findings provide further support for theories that assume that ADHD is a heterogeneous disorder and highlight the importance of comprehensive assessment using neuropsychological tasks in advancing the ability to design personally adjusted interventions for individuals with ADHD.

Acknowledgement: Minducate center, Sagol-School of Neuroscience, Tel-Aviv University

56.350 **Mental rotation performance in aphantasia** Zoe Pounder[1](z.i.e.pounder@gmail.com), Jane Jacob[2], Christianne Jacobs[3], Catherine Loveday[4], Tony Towell[5], Juha Silvanto[6]; [1]University of Westminster, [2]University of Louisiana, USA, [3]Universite Catholique de Louvain, Louvain-la-Neuve, Belgium, [4]University of Westminster, [5]University of Westminster, [6]University of Westminster

Our ability to form visual images within our mind is known as visual mental imagery and enables us to draw on internal representations in the absence of external stimuli. Aphantasia, a recent condition to gain attention within the field of visual neuroscience, describes the experience of individuals who lack voluntary visual mental imagery. The majority of research in this area has stemmed from subjective reports of visual imagery, through questionnaires such as the Vividness of Visual Imagery Questionnaire (VVIQ). More recently, a few studies have investigated impairments in cognitive function; however, these studies are limited in terms of the low sample size of aphantasic individuals used within the studies. As yet, no study has explored mental rotation (MR) performance in congenital aphantasics. Using the classic Shepard and Metzler MR paradigm, here we examine MR performance in 20 individuals with congenital aphantasia, as well as measuring self-reported visual object and spatial imagery through questionnaires (VVIQ, Spontaneous Use of Imagery Scale and Object-Spatial Imagery Questionnaire). We find that aphantasic participants self-report higher scores for visual spatial imagery compared to object imagery scores, which were below average of the object imagery scores reported by controls. Furthermore, in the MR test, aphantasic individuals took longer to rotate the stimuli compared to controls, and this time increased in line with the increased level of difficulty of rotation. Despite aphantasics taking longer to mentally rotate stimuli compared to controls, aphantasic participants were more accurate then control participants across all levels of difficulty. Our results indicate that aphantasics use a different strategy when performing the MR task, leading to slower reaction times but higher accuracy.

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56.351 **Autistic and positive schizotypal traits modulate cognitive control tendencies** Ahmad Abu-Akel[1](ahmad.abuakel@unil.ch), Julie Ramain[1], Chrisitne Mohr[1]; [1]Institute of Psychology, University of Lausanne

Introduction: Independent lines of evidence suggest that autism and schizophrenia and the broader spectrum of their traits in neurotypical participants are associated with dysfunction in attention and cognitive control. However, recent evidence suggests that these conditions can co-occur at both the diagnostic and trait levels more than would be expected by chance. While a traditional view of these conditions suggests that such co-occurrence worsens attentional abilities, the 'diametric brain theory' posits opposing effects. Method: To test these contrasting hypotheses, autism traits and psychosis proneness were evaluated in tandem in 83 neurotypical adults (34 Females), on the assumption that autism tendencies and psychosis proneness are dimensions of normal variation. Attentional and cognitive control abilities were assessed using the AX-CPT task, where target (AX) trials occurred with 70% frequency, and nontarget trials occurred with 30% frequency evenly divided among AY, BX and BY trials. Results: Poisson regressions reveal that autism tendencies and psychosis proneness interactively reduced both omission (AX) and commission (AY) errors, such that the reduction is greatest when both tendencies are high than when both are low. On the other hand, psychosis proneness was associated with increased BX errors. Conclusion: The results suggest that autism tendencies and psychosis proneness interactively improve sustained attention and enhance cognitive control by reducing pre-potent response tendencies. The association of psychosis proneness with increased BX errors, suggest that reactive tendencies are enhanced in psychosis prone individuals. These results emphasize the importance of the simultaneous assessment of autism and psychosis to understanding attentional abilities in autism and schizophrenia spectrum disorders.

56.352 **Approach motivation and narrowed attentional breadth following self-control: investigating the role of asymmetrical frontal activity** Brent Pitchford[1](bp11lj@brocku.ca), Karen M Arnell[1]; [1]Psychology, Brock University

People often inhibit or override their dominant response tendencies in order to successfully complete tasks. This process is referred to as self-control. While considering people's approach-motivated tendencies, Schmeichel, Crowell and Harmon-Jones (2016) determined that completing self-control was associated with increased relative left frontal cortical activity and Harmon-Jones and Gable (2009) determined that greater left frontal cortical activity was associated with narrowed attention. Based on these findings, it was predicted that greater left frontal activity would result in narrowed attention after exercising self-control. The purpose of the current study was then to examine whether people's attentional breadth would relate to their frontal asymmetry after completing an incongruent color Stroop task (i.e., indicating the ink colors of mismatching color words), as this is a common self-control manipulation used in past research. Attentional breadth, or whether people focused on the 'forest' or the 'trees', was indicated by reaction time differences between when the two target letters (T, H) were presented in the global and local levels of the hierarchical Navon letter stimuli. An equal number of trials were presented both before and after the Stroop task. The change in attentional breadth (i.e., post Stroop - pre Stroop) was associated with people's naturally occurring approach motivation - as indexed by their Behavioural Activation System (BAS) scores; attentional breadth following the self-control task was negatively related to BAS. As well, the breadth of attention and self-report measures were related to frontal alpha asymmetry (i.e., lateralized cortical activity in the frontal regions) during an initial resting session as well as during the pretrial period between the offset of fixation and the onset of the Navon letter stimuli. The present findings provide further evidence that both motivation and self-control can influence attentional breadth, and give us a better understanding of the role of asymmetrical frontal cortical activity.

Acknowledgement: NSERC

56.353 **Exposure to acute psychosocial stress modulates the effect of cue validity in an attention orienting task.** Stuart M Pugh[1](smp1g15@soton.ac.uk), Tamaryn Menneer[2], Dominic Taunton[3], Matt J Garner[1], Nick Donnelly[1]; [1]School of Psychology, University of Southampton, [2]Medical School, University of Exeter, [3]Southampton Marine and Maritime Institute, University of Southampton

Previously we have reported that attentional alertness improves in the period immediately following exposure to an acute psychosocial stressor (Pugh et al., 2017). Pugh et al. also reported an unexpected effect of stress on the cue validity effect following exposure. The cue validity effect was modulated by time from the stressor. The experiment reported here seeks to confirm and extend the finding of a time-contingent effect of stress on orienting. Participants responded to the direction of a central arrow, flanked by pairs of distractors and comprised of two cue conditions (valid/invalid), two target conditions (congruent/incongruent) and two cue-target intervals (400/800ms). Each run of the orienting task took around 15-minutes (384 trials). Participants completed the task three times. First in a baseline run (T1). Second, immediately after participants had completed either a psychosocial stressor (Socially-Evaluative Cold Pressor Task – Schwabe et al., 2008) or comparable control (T2). Third, at a time point 20-minutes after completing the stressor / control (T3). T2 and T3 measured orienting at time points in line with recognised maximal physiological reactions to stress (Sympathetic Nervous System and Hypothalamic-Pituitary-Adrenal Axis). Stress state was recorded using self-report measures (SSAI, Spielberger, 1989; adapted NASA-TLX, Hart & Staveland, 1998) and demonstrated successful stress induction. The results confirmed the finding of Pugh et al. (2017), that cue validity effects are differentially affected by stress at T2 and T3 relative to baseline (T1). The results suggest that the pattern of cue validity effects that are measured over repeated blocks of the orienting task are subject to both practice and fatigue effects in controls. However, in the stress group, exposure to the acute psychosocial stressor prevented the emergence of an enhanced cue validity effect at T2. These results are discussed in terms of the influence of stress on broader aspects of the attentional networks.

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56.354 **Instructor presence, working memory capacity and learning from instructional video** Jiahui Wang[1](jwang01@ufl.edu), Palvo Antonenko [1], Ethan Fieldman[2], Ashley Fieldman[2]; [1]School of Teaching and Learning, University of Florida , [2]Study Edge LLC

With the continued expansion of online learning, many popular online education platforms use instructional videos that integrate a real instructor next to the learning material. The instructor explains the material and displays non-verbal cues such as facial expression, body gesture, and eye contact. The instructor video and the learning content in the rest of the frame represent two potentially competing sources of information on the screen and they can place different demands on learners' attentional control and working memory processes. Working memory capacity is a theoretically important moderator of visual attention, cognition, and learning in this context. The current study aims to explore how instructor presence in instructional video influences learning and visual attention distribution and how these effects are moderated by individual differences in working memory capacity. Automated Operation Span task was used to assess individual differences in working memory capacity at the before the experiment. Sixty participants watched two 4-minute instructional videos on Statistics topics - Terminology associated with Observational Studies and Experiments (basic topic), and Rationale for Analysis of Variance (advanced topic). Each video was presented either with or without instructor presence, and participants' eye movement data were simultaneously recorded. Then, participants completed a learning test that measured retention and transfer of knowledge from the two videos. Findings indicated the instructor attracted a significant amount of attention while it is present for both topics - 35% of the total dwell time for the basic topic and 37% for the advanced topic. Also, the instructor presence improved participants' ability to transfer information from the advanced topic, $F(1, 58) = 4.464$, $p < .05$, $\eta 2 = .071$. Finally, working memory capacity is a significant predictor of participants' retention of knowledge from the basic topic, controlling for instructor presence ($b = .051$, $t(55) = 3.358$, $p < .001$).

56.355 **Motivated attention in the perception and action of climate change** Jiaying Zhao[1,2](jiayingz@psych.ubc.ca), Yu Luo[1]; [1]Department of Psychology, University of British Columbia, [2]Institute for Resources, Environment and Sustainability, University of British Columbia

Despite the overwhelming scientific evidence, many people still remain skeptical about climate change and refuse to take actions to mitigate the adverse impacts of climate change. Here we propose a motivated attention framework to explain public skepticism and inaction. We propose that personal motivations (e.g., political orientation) shape attention to climate change information, which alters the perception of climate evidence and shifts subsequent actions to mitigate climate change. In Study 1 (N=700), participants viewed a graph representing the annual global temperature change from 1880 to 2014 and estimated the average temperature change. We found that participants gave a higher estimate when the data were framed as global temperature than when the temperature label was removed (in a neutral frame). Furthermore, political orientation predicted participants' estimation in that conservatives under-estimated the temperature change compared to liberals. In Study 2 (N=214), we eyetracked participants' gaze when they viewed the temperature graph, and found that liberals focused more on the increasing phase of the curve, which was associated with a higher estimation of the global temperature change. However, conservatives focused more on the flat phase of the curve, which was associated with a lower temperature estimation. In Study 3 (N=104), we found that the total amount of gaze fixations of liberal participants on the graph predicted their willingness to donate to environmental organizations and their donation amount. These results provide initial evidence for the motivated attention framework, highlighting an attentional divide between liberals and conservatives in the perception of climate data, which can further explain their polarizing beliefs about climate change, as well as the actions these individuals take to address climate change. The current findings have important implications for the visualization of climate data and communication of climate science to different socio-political groups.

56.356 **Transfer of Pseudoneglect in a Theory of Mind Task** Branden J Bio[1](bbio@princeton.edu), Taylor W Webb[1], Michael SA Graziano[1]; [1]Department of Psychology, Princeton University

Many people show an intrinsic bias in visuospatial processing called pseudoneglect – some are better at processing objects to the right, whereas others are biased to the left. We measured pseudoneglect in neurotypical participants using a variant of the line bisection task. In the same participants, we measured performance in a social cognition task. This theory of mind task measured whether each participant had a processing-speed bias toward the right of, or left of, a cartoon agent about which the participant was thinking. Crucially, the cartoon was rotated such that what was left and right with respect to the cartoon was up and down with respect to the participant. Thus, a person's own left-right bias could not align directly onto left and right with respect to the cartoon head. Performance on the two tasks was significantly correlated. People who had a natural bias toward processing their own left side of space were quicker to process how the cartoon might think about objects to the left side of its face, and likewise for a rightward bias. One possible interpretation of these results is that the act of processing one's own personal space, and the act of reconstructing someone else's processing of their space, uses at least partially shared mechanisms.

Multisensory Processing: Vision and audition

Tuesday, May 22, 2:45 - 6:45 pm, Banyan Breezeway

56.357 **Both Intra- and Supra-Modal Time Perception Mechanisms Exist: Evidence from Debut Chronostasis** Shinsuke Shimojo[1](sshimojo@caltech.edu), Yong-Jun Lin[1], William Liang[1]; [1]Computation and Neural Systems / Biology & Biological Engineering, California Institute of Technology

Are the neural mechanisms underlying time perception specific to each sensory modality or supra-modal? We found evidence for both in a time illusion that in a repeating item sequence, the first one appears to last longer ("debut chronostasis"). In a four-item sequence paradigm, debut chronostasis magtitude (DCM) was measured by a duration discrimination task comparing the first and the second items. We have previously found that visual debut chronostasis would occur only if the first item had variable duration across trials and disappear if it had constant duration. We explained the results with uncertainty of an internal duration template that could be perturbed by a variable-duration first item. Here we further tested whether the internal duration template is intra- or supra-modal. In Experiment 1 (N=19), the variable item was the first one (debut chronostasis expected); in Experiment 2 (N=8), the second one (no debut chronostasis expected). In both experiments, the modality of the first and the second items were V-V (visual), A-A (auditory), V-A, or A-V. Were intramodal mechanisms exist, DCM would be stronger in the within- than in the cross-modal conditions in Experiment 1; Were duration templates entirely intra-modal, the certainty of the first-item duration in Experiment 2 would reduce DCM compared to Experiment 1 only in the within-modal conditions. Were debut chronostasis entirely a supra-modal, DCM would be the same in the within- and the cross-modal conditions in Experiment 1. The results showed that 1) in both experiments, DCMs were higher in within-modal conditions, suggesting an intra-modal stage of mechanisms and 2) when the duration of the first-item was constant in Experiment 2, DCMs in all four conditions of were lower than those in Experiment 1 by similar amount, suggesting the existence of supra-modal mechanisms. Thus, we found evidence for both intra- and supra-modal stages of time perception.

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56.358 **Hand Dominance Can be Effectively Eliminated by Sensory Dominance during Multisensory Competition** Shiyong Chen[1](261888687@qq.com), You Li[1], Lu Shen[1], Jing Xia[1], Yizhou Jiang[1], Yuqian Yang[1], Qi Chen[1]; [1]Center for Studies of Psychological Application and School of Psychology, South China Normal University, Guangzhou 510631, China, [2]Guangdong Key Laboratory of Mental Health and Cognitive Science, South China Normal University, Guangzhou 510631, China

The classical Colavita effect refers to the phenomenon that when presented with unimodal auditory, unimodal visual, and bimodal audiovisual stimuli in a speeded discrimination task, participants tend to only respond to the visual stimuli and ignore the auditory stimuli in the audiovisual condition. However, it is reported that the tendency varied when participants used different hands to respond to different sensory stimuli. The relationship between hand dominance and sensory dominance is remained unknown. We conducted the first experiment on the Colavita effect in which participants were asked to respond to the dominant sensory modality with dominant hand while respond to the non-dominant sensory modality with non-dominant hand in one task, and respond to dominant sensory modality with non-dominant hand while respond to the non-dominant sensory modality with non-dominant hand in the other task. We found that participants could be divided into two groups according to their response modes between hand dominance and sensory dominance in the unimodal trials, one referred to dominant hand dominated when processing visual stimuli, and non-dominant hand dominated when processing auditory stimuli. The other referred to non-dominant hand dominated when processing visual stimuli, and dominant hand dominated when processing auditory stimuli. The same pattern was observed in bimodal trials, dominant hand dominated when vision dominated audition, and non-dominant hand dominated when audition dominated vision in one group. However, non-dominant hand dominated when vision dominated audition, and dominant hand dominated when audition dominated vision in the other group. The interaction between hand dominance and sensory dominance was also found when the ratios of unimodal and bimodal trials changed in Experiment 2, which suggested that stimuli proportion did not modulate the interaction between hand dominance and sensory dominance.

56.359 **Audiovisual combination with temporal correlation and time pressure** Robert Sekuler[1](vision@brandeis.edu), Yile Sun[1], Timothy J Hickey[2]; [1]Volen Center, Brandeis University, [2]Computer Science, Brandeis University

We built a video game to examine how temporal correlation and increasing time-pressure influenced audiovisual integration. We supplemented behavioral indices of integration with pulse rate measures and EEG from a frontal and temporoparietal electrodes in a wearable sensor band with. METHOD. Visually identical fish swam into view one at a time. Each oscillated sinusoidally in size —either at 5 or 8Hz. Most fish were accompanied by a sound that amplitude modulated —either at 5 or 8Hz. Modulation frequency was either matched to the frequency of visual oscillation (Congruent) or was mismatched to it (Incongruent). A Control condition omitted the sound. Fish of all kinds were randomly intermixed. Subjects were instructed to ignore sounds, categorizing fish solely on their frequency of visual oscillation. In Experiment One, each fish remained visible for two seconds or until the subject's response. The interval between successive fish was fixed at 1.6 sec. In Experiment Two, fish again remained visible for up to two seconds, but the interval between successive fish systematically decreased each 90 seconds, from 1.6 sec down to 400 msec. RESULTS. Experiment One. The Congruent condition produced significantly faster and more accurate responses than other conditions; Incongruent and Control conditions did not differ from one another. Theta band (4-7Hz) power from FP electrodes increased substantially ~300 msec after fish onset, but only for Incongruent fish. Experiment Two. Diminishing inter-fish intervals caused subjects to reduce the time spent observing the stimulus, which increased errors. Mean pulse rate increased modestly, but systematically with time-pressure. CONCLUSIONS. Audiovisual congruence boosted performance, but incongruence had no discernible behavioral effect. However, theta band EEG signals did differentiate conditions, perhaps because mismatched audio and visual signals demanded increased cognitive control. Reduced time between fish induced subjects to needlessly curtail observation times, a self-defeating strategy.

56.360 **Complex interactions across modalities in audio-visual cross-modal statistical learning** Helga Reguly[1](reguly_helga@phd.ceu.edu), Márton Nagy[1], József Fiser[1]; [1]Department of Cognitive Science, Central European University

Statistical learning (SL) within modalities is an area of intensive research, but much less attention has been focused on how SL works across different modalities apart from demonstrating that learning can benefit from information provided in more than one modalities. We investigated visuo-auditory SL using the standard arrangement of SL paradigms. Four visual and four auditory pairs were created from 8-8 abstract shapes and distinctive sounds, respectively. Visual pairs consisted of two shapes always appearing together in a fixed relation, audio pairs were defined by two sounds always being heard at the same time. Next, strong and weak cross-modal quadruples were defined as one visual pair always occurring together with a particular auditory pair (strong) or appearing with one of two possible auditory pairs (weak). Using additional individual shapes and sounds, a large number of cross-modal six-element scenes were created with one visual pair, a single shape, one sound pair and a single sound. Adult participants were exposed to a succession such cross-modal scenes without any explicit task instruction during familiarization, and then tested in three familiarity tests: (1) visual or auditory pairs against pairs of randomly combined elements unimodally, (2) strong cross-modal quads against weak ones, and (3) visual or auditory pairs from the strong and weak quads against each other, again unimodally. We arranged relative difficulties so that in Test 1, the visual pairs were highly favored against random pairs, while choosing the auditory pairs against random sound pairs was at chance. Surprisingly, this setup caused participants choosing the weak quads significantly more often as familiar constructs in Test 2, and preferring equally strongly both the visual and auditory strong pairs over the corresponding weak pairs in Test 3. We interpreted this complex interaction through probabilistic explaining away effects occurring within the participants' emerging internal model.

56.361 **Acquirement of cross-modal correspondence from mere experience** Asumi Hayashi[1](asumi@l.u-tokyo.ac.jp), Kazuhiko Yokosawa[1]; [1]The University of Tokyo

Cross-modal perception implies we know which signals belong together and how features relate. Previous studies have demonstrated a correspondence between different sensory features can be acquired through perceptual learning (Ernst, 2007; Seitz et al., 2007). However, it remains uncertain whether we can extract the structure of cross-modal correspondence when we merely learn several one-to-one correspondences. This study investigated whether subjects can extract the occurrence of correspondences between visual space and auditory pitch from a few stimuli. In the experiment, 5/10/15 pairs of a pure tone and a small black circle on a display were presented consecutively. Four rules - 'the higher pitch and the higher position,' 'the higher pitch and the more to the right position,' and the reverse of each, respectively with a 25 percent possibility – governed presentation of the stimuli. The frequency of the pure tone (200-900Hz, by 1Hz) and the position of the circle (700□pxs, by 1px) were variable, but they were either related to each other based on one of these 4 rules or they were not related. After these clue stimuli, only a pure tone (200/375/550/725/900Hz) was presented and the participants guessed the position of the circle. We predicted if the subjects succeed in rule extraction, they could deduce the circle height or right-left position corresponded to the auditory pitch according to the rule. Results indicate deduced circle height or right-left position mapped linearly along with pitch height in accordance with each rule. This means participants could extract the rule and prefigure the circle position quite precisely when 10 or 15 clue stimuli were presented; even with five clue stimuli considerable precision was observed. These results suggest we can acquire occurrence of cross-modal correspondence between visual space and auditory pitch from mere experience and render according predictions.

56.362 **Audiovisual Competition in the Line Motion Illusion**

Amanda J Sinclair[1](ajs857@mail.usask.ca), Aidan J Wickenhauser[1], Chamin D Wanasundara[1], Steven L Prime[1]; [1]Psychology, Arts and Science, University of Saskatchewan

The Line Motion Illusion is characterised as illusory perception of a solid line appearing to grow away from a preceding visual or auditory cue. This illusion is attributed to the widening of spatial attention after attention has been narrowly captured to the cue's location. Although this illusion has been found using either visual or auditory cues (Shimojo, Miyauchi, & Hikosaka, 1997), it has yet to be examined under different crossmodal conditions where cues from different modalities may either enhance or compete in capturing attention when cues are spatially congruent or incongruent. Subjects' perception of the illusion was assessed under spatially congruent and incongruent crossmodal conditions using auditory and visual cues. In the congruent condition, the auditory cue (a short tone) and the visual cue (a flash) were both presented on the same side of the display (either left or right). In the incongruent condition, the cues were presented simultaneously on opposite sides. These crossmodal conditions were compared to unimodal conditions of only visual or auditory cues. We also manipulated the time interval between the presentation of cues and bar to assess the extent to which the illusion depended on the timing of the cues. Eye position was monitored via an SMI RED eye tracker to ensure they maintained fixation. Overall results show similarly high rates of reporting the illusion across all conditions (73-90%). However, in the incongruent crossmodal condition subjects reported the illusory motion from visual cues significantly more than the auditory cues. We also found the illusion depended on the relative timing between the cues and the bar. Our findings provide new insights into the extent to which visual and auditory cues compete in the putative capture of attention to produce the line motion illusion.

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56.363 **A common mechanism processes auditory and visual motion**

David Alais[1](david.alais@sydney.edu.au), Uxía Fernández Folgueiras[2], Johahn Leung[1]; [1]School of Psychology, University of Sydney, Australia, [2]Department of Biological Psychology & Health, Universidad Autónoma de Madrid, Spain

Neuroimaging studies suggest human visual area V5, an area specialised for motion processing, responds to movement presented in the visual, auditory or tactile domains. Here we report behavioural findings strongly implying common motion processing for auditory and visual motion. We presented brief translational motion stimuli drifting leftwards or rightwards in either the visual or auditory modality at various speeds. Using the method of single stimuli, observers made a speed discrimination on each trial, comparing the current speed against the average of all presented speeds. Data were compiled into psychometric functions and mean perceived speed was calculated. A sequential dependency analysis was used to analyse the adaptive relationship between consecutive trials. In a vision-only experiment, motion was perceived as faster after a slow preceding motion, and slower after a faster motion. This is a negative serial dependency, consistent with the classic 'repulsive' motion aftereffect (MAE). In an audition-only experiment, we found the same negative serial dependency, showing that auditory motion produces a repulsive MAE in a similar way to visual MAEs. A third experiment interleaved auditory and visual motion, presenting each modality in alternation to test whether sequential adaptation was modality specific. Whether analysing vision preceded by audition, or audition preceded by vision, negative (repulsive) serial dependencies were observed: a slow motion made a subsequent motion seem faster (and vice versa) despite the change of modality. This result shows that the motion adaptation was supramodal as it occurred despite the modality mismatch between adaptor and test. We conclude that a common mechanism processes motion regardless of whether the input is visual or auditory.

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56.364 **Visual motion perception is influenced by sound pitch and location**

Prachi FNU[1](prx003@mail.usask.ca), Steven L Prime[1]; [1]Department of Psychology, University of Saskatchewan

Prior research has shown that auditory pitch can influence spatial and motion estimates of visual stimuli. Cross-modal correspondence between pitch and space show high-pitched sounds are associated with upper space and low-pitched sounds with lower space (Evans & Treisman, 2010). Ambiguous motion stimuli are perceived as moving upward when paired with ascending pitch sounds and downward with descending pitch sounds (Maeda, Kanai, & Shimojo, 2004). However, the extent to which pitch sounds influence visual motion remains unclear. Also, how manipulating both a sound's pitch and location might influence visual motion perception has not been explored before. Therefore, we investigated how changes in pitch tones affect visual motion direction judgments while varying visual motion saliency and the pitch-spatial location relationship relative to the direction of a visual motion stimulus. Participants were presented with high or low pitch tones with a random dot kinematogram (RDK) stimulus displaying either upward or downward motion. Saliency of visual motion was manipulated by systematically varying the degree of coherent motion. In Experiment 1, the auditory stimuli were presented from two speakers placed left and right of the RDK display. In Experiment 2, the auditory stimuli were presented from either a speaker above or below the RDK display. Subjects had to judge the direction of the coherent motion dots by a 2AFC response. Experiment 1 showed subjects were more likely to judge the direction of visual motion as going up with high-pitched tones and down with low-pitched tones. In Experiment 2, we found an interaction of sound location and pitch (low-pitch tones from the bottom speaker yielded greater judgment bias than low-pitch tones from the top speaker). These findings show the extent to which pitch affects visual motion perception as the strength of the visual signal is varied and how this pitch effect is sensitive to the pitch-space correspondence.

56.365 **Does audible sound modulate the potency of visual motion when that motion is suppressed from awareness by continuous flash suppression?**

Minsun Park[1](vd.mpark@gmail.com), Chai-Youn Kim[1]; [1]Department of Psychology, Korea University

Audible sounds naturally associated with specific visual stimuli can potentiate awareness of those stimuli during binocular rivalry (Chen et al., 2011; Lee, M., et al., 2015), implying formation of semantically congruent multisensory associations outside of awareness. Is awareness required for establishment of multisensory congruence between low-level sensory information? We have utilized the translational motion aftereffect (MAE) putatively mediated by direction-selective neurons and known to be attenuated by interocular suppression (Blake et al., 2006). MAEs were generated by 8-sec presentations of a pair of monocularly viewed, vertical gabor patterns comprising separate parts above and below central fixation. One pattern moved either leftward or rightward and the other remained stationary. For the visible adaptation condition, MAE contrast dependence was measured over a 1.5-log unit range, allowing selection of a non-satu-

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rated contrast for the main experiment. For the invisible adaptation condition, both gabor patterns were reliably rendered invisible by interocular continuous flash suppression (CFS; Tsuchiya & Koch, 2005). Leftward or rightward moving sound was mimicked by varying interaural intensity differences in white noise presented over headphones. Audiovisual motion could be either congruent or incongruent in direction, but owing to the potency of CFS participants were unaware of the congruence and of the location of moving gabor pattern. Following adaptation period, participants reported the duration, location (top vs bottom) and direction (leftward vs rightward) of the MAE experienced while viewing stationary gabor patterns. Among the five participants exhibiting clear dependence of MAE on gabor contrast, all showed reduced MAE duration when adaptation motion was suppressed by CFS. Of relevance to our question, MAE duration in the congruent condition was longer than in the incongruent condition, and no MAE was experienced on 26% of incongruent trials but only 15% of congruent trials. These results suggest that the low-level multisensory representations can be formed outside awareness.

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56.366 **Beep, be-, or –ep: The impact of auditory transients on perceived bouncing/streaming.** Hauke S Meyerhoff[1](h.meyerhoff@iwm-kmrc.de), Satoru Suzuki[2]; [1]Knowledge Media Research Center, Tuebingen, Germany, [2]Northwestern University, Evanston, IL, USA

Establishing object correspondence over time ("Which object went where?") is of central importance for a meaningful interpretation of the surrounding environment. Here, we study auditory contributions to this process using the bouncing/streaming paradigm wherein two discs move toward each other, superimpose, and then move apart. Critically, this event is ambiguous with regard to object correspondence as it is consistent with the interpretation of two discs streaming past each other as well as two discs bouncing off each other. When presented in silence, human observers tend to perceive streaming discs; however, a brief beep that coincides with the moment of visual overlap biases this impression toward bouncing. In four experiments, we tested the hypothesis that this crossmodal interaction is primarily mediated by low-level magnitude-based rather than high-level semantic-based processing. To do so, we orthogonally manipulated the number and semantic category of auditory transients. Specifically, different combinations of onsets and offsets generate qualitatively different events with distinct meanings; a single auditory transient can be a tone onset or a tone offset, and a pair of transients can be a brief tone (onset+offset) or a brief gap (offset+onset). The proportion of seeing bouncing increased with an increasing number of auditory transients (0 vs. 1 vs. 2) regardless of the sound's semantic category. For example, a tone onset and a tone offset were equally effective (relative to no transients), and a brief tone (onset+offset) and a brief gap (offset+onset) were equivalently more effective. We identified a critical window of ± 200 ms around the visual overlap; a longer tone whose offset occurred outside the window was only as effective as a single onset. These results suggest that a simple additive integration of auditory transients within the critical time window primarily mediates the auditory biasing of visual bouncing percepts.

56.367 **Faces and voices in the brain: RSA reveals modality-general person-identity representations in the STS** Maria S Tsantani[1](mariastephanie.tsantani@brunel.ac.uk), Nikolaus Kriegeskorte[2], Carolyn McGettigan[3], Lúcia Garrido[1]; [1]Division of Psychology, Department of Life Sciences, Brunel University London, [2]Zuckerman Mind Brain Behavior Institute, Columbia University, [3]Department of Psychology, Royal Holloway, University of London

Faces and voices can both trigger the recognition of familiar people. A large body of research has separately explored the recognition of familiar faces and voices, but here we investigated whether there are modality-general representations of person-identity that can be equally driven by faces or voices. Based on previous research, we predicted that such modality-general representations could exist in multimodal brain regions (e.g. Shah et al., 2001) or in unimodal brain regions via direct coupling of face and voice regions (e.g. von Kriegstein et al., 2005). In an event-related fMRI experiment with 30 participants, we measured brain activity patterns while participants viewed the faces and listened to the voices of 12 famous people. We defined multimodal, face-selective, and voice-selective brain regions with independent localisers. We used representational similarity analysis (RSA) with the linear discriminant contrast (LDC), a crossvalidated distance measure (Walther et al., 2016), to create representational distance matrices (RDMs) of all 12 people for each brain region. We created face RDMs, voice RDMs, and crossmodal RDMs. Each cell in one of these RDMs shows the neural discriminability of a pair of identities. For the crossmodal RDMs, these LDC distances show whether the discriminant based on the activity patterns of identity pairs in one modality can be used to differentiate the activity patterns of the same identity pairs in the other modality. Under the null hypothesis LDC distance is distributed around zero, and we therefore investigated which regions showed distances significantly greater than zero. Our results showed that the mean LDC distance for crossmodal RDMs was significantly greater than zero in regions of the mid and posterior superior temporal sulcus (STS) that showed multimodal responses. These results suggest that multimodal regions of the STS represent person identity in a similar way regardless of the input modality.

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56.368 **Comprehension of an audio versus an audiovisual lecture at 50% time-compression** Nicole Perez[1], Michael J Kleiman[1], Elan Barenholtz[1]; [1]Department of Psychology, College of Science, Florida Atlantic University

Time-compression—the speeding up of audio-visual presentations without an accompanying change in pitch— is a heavily used technique when viewing video lectures because it allows the same content to be viewed in a shorter duration. Previous studies have demonstrated that comprehension is affected when a lecture is compressed by 50% (i.e. two times the normal speed) or more. These findings have only considered multimedia recordings with text and figures. However, the visual properties of a speaker—present in an audiovisual, rather than just auditory stimulus— have been shown to enhance speech comprehension under other suboptimal conditions such as noise, low volume, and unfamiliar language. Here, we investigated whether the presentation of a speaker's face benefits comprehension of a time-compressed video. Participants listened to both original and 50% compressed lectures in both audio-only and audiovisual conditions (with different videos used for each of the four combinations of conditions). Eye movements were tracked during the audiovisual lecture. Afterwards, they were tested on their knowledge of the content of the lectures using a questionnaire. Results showed a main effect of speed with higher comprehension scores in the uncompressed conditions. In addition, comprehension scores were significantly better with the visual face than the audio-only condition in the compressed condition. Eye fixation analyses revealed that participants in the compressed condition looked less at the eyes and more at the nose, consistent with other studies finding more centralized fixations under suboptimal auditory conditions. Overall, these results suggest that audiovisual redundancy provides a benefit in encoding of time-compressed speech.

56.369 **The Contribution of Facial Motion to Voice Recognition** Noa Simhi[1](noa.louisa@gmail.com), Itai Linzen[1], Galit Yovel[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, [2]The Sagol School of Neuroscience, Tel-Aviv University

Visual and auditory processing are known to be linked in face perception: the famous McGurk effect demonstrates this integration and studies have shown that lip movements facilitate voice perception. These studies have primarily focused on speech perception however, and it is less clear what is the role of dynamic facial information in voice identity recognition.
In order to examine this question, we conducted an EEG experiment during which participants performed a voice recognition task: in a study phase they learned to recognize the identity of 4 voices, never seeing the faces corresponding to the voices. Afterwards, during a test phase, they indicated which voice was heard along with each stimulus. At test, voices were presented with either dynamic faces, static faces or alone. Behavioral findings show that voice recognition is both more accurate and faster when voices are presented with videos rather than alone, while voices presented with static faces yield faster but not more accurate voice recognition, thus indicating that facial motion contributes to voice recognition. To compare the contribution of dynamic and static faces to voice recognition, we subtracted the EEG responses to the face alone and voice alone from the response to the integrated face-voice stimulus, both

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in the static and dynamic conditions. The EEG results revealed a strong fronto-occipital effect of integration related to motion processing, 1 to 1.1 seconds after voice onset. These results indicate that dynamic facial information contributes to voice recognition even when voices are learned without faces. Thus, dynamic identity signatures available in lip movements may be linked to voices and facilitate voice recognition, even when the signatures themselves are not studied.

56.370 **Weems vs Wums: Random Shapes with Distinct Edges and Fast Motion are More Often Classified as "Weems", and One's that are Blurry and Slow as "Wums"** Michael K. McBeath[1](m.m@asu.edu), R. Chandler Krynen[1], K. Jacob Patten[1], Seth D. Gory[1]; [1]Department of Psychology, Arizona State University

Introduction: The Bouba-Kiki Effect is that observers favor assigning the nonsense-words "bouba" to rounded-edged random-shapes and "kiki" to jagged-edged random-shapes. This correlation is typically cited as evidence for synesthesia-type connections between consonant phonetic attack sounds and visual shape contours. Our study examines if vowel phonetic characteristics are also coupled to other visual object features. We hypothesized that nonsense-words with vowel phonemes associated with higher pitch-height will be assigned to visual shapes that have distinct edges and move rapidly, and conversely, those with vowel phonemes associated with lower pitch-height will be assigned to shapes that have blurry edges and move slowly. Methods: 51 participants observed pairs of random visual-shapes along with pairs of nonsense-words that were also verbally spoken, and judged which nonsense-word best matched each shape. Each nonsense-word pair had the same beginning and ending consonant phonemes, only differing in the vowel portion being either a high pitch-height i: sound (as in "weem"), or a low ^ sound (as in "wum"). Results: The findings confirm our hypothesis that i: nonsense-words (like "weem") are more likely to be assigned to random-shapes that have distinct-edges and move rapidly, and ^ nonsense-words (like "wum") are assigned to random-shapes that have blurry edges and move slowly (z values varied between 2.0 and 5.9). We also replicated the Bouba-Kiki Effect, and failed to find a relationship between phonemes and control visual features such as height-in-the-plane, which provides some evidence against demand characteristics. Conclusions: We replicated and extended the Bouba-Kiki Effect with findings supporting that the vowel phoneme dimension of pitch-height is associated with visual shape characteristics of edge distinctiveness and motion speed. "Weems" are more distinct and fast, while "wums" are more blurry and slow. These findings are consistent with a multisensory mapping based on functional natural patterns of acoustics, visual shape, and motion speed.

56.371 **An Electroencephalography Investigation of the Differential Effects of Visual versus Auditory Attention on Crossmodal Temporal Acuity** Leslie D Kwakye[1](lkwakye@oberlin.edu), Kathryn K Hirabayashi[1], Zoii Barnes-Scott[1], Samantha L Papadakis[1]; [1]Neuroscience Department, Oberlin College, Oberlin, OH, USA

Our perception of the world hinges on our ability to accurately combine the many stimuli in our environment. This multisensory integration is highly dependent on the temporal relationship between unisensory events and our brain's ability to discern small timing differences between stimuli (crossmodal temporal acuity). Our previous research investigated whether attention alters crossmodal temporal acuity using a crossmodal temporal order judgment (CTOJ) task in which participants were asked to report if a flash or beep occurring at different time intervals appeared first while concurrently completing either a visual distractor or auditory distractor task. We found that increasing the perceptual load of both distractor tasks led to sharp declines in participants' crossmodal temporal acuity. The current study uses electroencephalography (EEG) to understand the neural mechanisms that lead to decreased crossmodal temporal acuity. Participants completed a CTOJ task in association with a visual distractor task, as described above, while EEG activity was recorded from 64 scalp electrodes. EEG activity was averaged based on the onset of the flash, producing an event-related potential (ERP) waveform for each perceptual load level and stimulus onset asynchrony (SOA) combination. Preliminary data analysis suggests that increasing perceptual load most strongly influences the amplitude of the N1/P2 complex in response to the flash across parietal electrodes. This suggests that decreases in crossmodal temporal acuity with increasing visual load may be mediated by alterations in visual processing. Ongoing data collection investigates whether increasing auditory load will lead to alterations in auditory processing, thus suggesting a modality-specific mechanism for disruptions in crossmodal temporal acuity. This line of research serves to illuminate the neural networks that underlie the interaction between attention and multisensory integration.

56.372 **Does a salient auditory stimulus always impair visual memory?** Keiji Konishi[1](konishi@l.u-tokyo.ac.jp), Ryoichi Nakashima[1], Kazuhiko Yokosawa[1]; [1]The University of Tokyo

Previous research shows that a salient item in a scene leads to impaired memory for peripheral information (Christianson, 1992). This saliency effect has been investigated mainly within visual modality. However, it is unclear whether visual memory can be disturbed by stimulation in other modalities. This study examined the impact of a salient auditory stimulus on visual memory. We asked participants to view a stream of 156 faces and press a key if they detected a face of a specific gender. Importantly, half of all faces were immediately followed by a loud pure tone, whereas other faces were presented alone (Experiment 1) or followed by a soft tone (Experiment 2). To check the manipulation of saliency of tones, we analyzed RTs to faces, based on the suggestion about auditory alerting (Stahl & Rammseyer, 2005). Because the RTs to faces presented with loud tones were found shorter than those with soft tones or without tones, we defined loud tones as salient in both experiments. After this face detection task, participants completed a 2AFC recognition task for surprise memory test. Interestingly, the loud tones affected recognition performance differentially in these experiments. In Experiment 1 accuracy for faces with loud tones was worse than those without tones whereas in Experiment 2, accuracy for faces with loud tones was better than those with soft tones. This difference implies that participants dealt with these stimuli (i.e., faces and tones) based on a prior assumption. In Experiment 1, faces and tones were perceived separately because tones were not always presented. In Experiment 2, each face may be bound with the co-occurring tone into a unitary multisensory event, because both stimuli existed in every trial. In conclusion, the effect by a salient tone can spread over the face representation when both tone and face presentation made the "audio-visual unity."

56.373 **Cross-modal attenuation of misophonic responses** Patrawat Samermit[1](psamermi@ucsc.edu), Jeremy Saal[1], John Collins[1], Nicolas Davidenko[1]; [1]Psychology Department, University of California, Santa Cruz

Misophonia, defined as "hatred of sound", is a disorder in which certain sounds (e.g., the screech of nails on a chalkboard) trigger strong negative emotional and visceral reactions including disgust, anxiety, and anger. The mechanisms of misophonia are not well understood, although it has been described as a cross-modal neural mapping (Edelstein, Brang, Rouw, & Ramachandran, 2013). We propose that misophonia involves multi-sensory simulation of the apparent source of the sound. If this is true, a grating sound that is normally associated with a grating activity will feel less grating if it is visually associated with a non-grating activity. In this study, neurotypical participants were presented with eight short sound clips that have been reported in previous research to produce misophonic responses, such as the sound of nails on a chalkboard or a knife scraping across glass. Each sound was paired with either a negative attributable video (e.g., the original video of nails scratching a chalkboard) or a positive attributable video (e.g., someone playing the flute). The pairing was counterbalanced across participants. Participants were first presented with all eight sounds with no video, to obtain baseline ratings of (un)pleasantness, (dis)comfort, and bodily sensation. They were then presented with the same 8 sounds paired with 4 positive and 4 negative attributable videos in random order. Finally, they were presented with the 8 sounds again with no video. Comparing ratings across blocks indicates that the concurrent presentation of a positive (or negative) attributable video leads to more positive (or negative) responses to sounds than baseline, across all three measures, which then returns to baseline upon the third presentation with no video. Our results provide evidence that the negative responses associated with grating misophonic sounds may be cross-modally attenuated through association with less grating visual stimuli.

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Object Recognition: Neural Mechanisms

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56.401 **Is the use of visual predictions dependent on expected target difficulty?** Sage EP Boettcher[1](sage.boettcher@psy.ox.ac.uk), Freek van Ede[1], Anna C Nobre[1]; [1]Department of Experimental Psychology, University of Oxford

The use of predictions in adaptive perception is becoming increasingly recognized. Here we asked whether predictions regarding the identity of upcoming visual targets are used differently when these targets are expected to be more difficult to perceive. Participants monitored a stream of objects with the task of detecting two pre-specified target objects. Different cues predicted either of two different targets, of which one was always significantly more difficult to perceive as a result of a shorter target-mask SOA. Behaviorally, we find a significant interaction between the target difficulty and the presence of a cue in both reaction times and accuracy. Analysis of the event related potentials locked to the onset of the cue (item 1) preceding a target (item 2) indicates an effect of informative cues relative to neutral cues, and also suggests a modest late positivity associated with the difficult relative to the easy cue. ERPs locked to the target show a strong interaction between the two variables – cue presence and target difficulty. Finally, we used multivariate pattern analysis (MVPA) to investigate whether the identity of the predicted target could be decoded during the cue period, and whether this also depends on expected difficulty. Preliminary analysis indeed confirms above chance decoding of the predicted target within the cue period, albeit with no clear effects of expected target difficulty. This indicates that subjects may activate a 'template' of the upcoming target during the cue period. Together, our results show that cues may be used differently when an upcoming target is more difficult to perceive, but that the exact nature of this difference may manifest differently in behavior, preparatory neural activity, and post-target neural activity.

56.402 **Electrophysiological Evidence for the Tripartite Organization of the Ventral Stream by Animacy and Object Size** Joseph D Borders[1](borders.9@wright.edu), Birken T Noesen[1], Assaf Harel[1]; [1]Wright State University

One recurrent finding in the neuroimaging of vision is category-selective regions in occipitotemporal cortex (OTC). It is still unclear, however, how object information is organized in OTC. Konkle and Caramazza (2013) suggested that object representations in OTC are organized based on their animacy and real-world size. These two dimensions, they argue, do not operate independently, but rather interact; small and large inanimate objects are represented in separate OTC regions, while in contrast, animate objects are grouped together irrespective of their size. We investigated the early neurophysiological signatures of this organizational principle by asking whether the N1, a category-selective event-related potential (ERP) component, is differentially affected by animacy and size. We recorded ERPs from participants while they viewed object images from four categories spanning animacy (Inanimate: roller-skate, motorbike; Animate: cow, butterfly) and size (Large: motorbike, cow; Small: roller-skate, butterfly) dimensions. To ensure active categorization of the objects along all dimensions, participants were asked to categorize the objects based on their size and animacy (as well as based on physical properties, as a control condition). We found that the combined effect of animacy and size can be observed as early as 170ms post-stimulus onset. Specifically, there was a significant interaction effect on N1 amplitude reflecting the organizational principle suggested by Konkle and Caramazza: N1 amplitude in right posterior lateral regions was more negative for animate than inanimate objects, and critically, size had an effect on N1 amplitude which was evident only for inanimate objects. A more negative response was recorded in response to large objects compared to the small objects. Together, these data support previous neuroimaging findings suggesting object representations in OTC are represented based on their animacy and size, and, importantly, indicate that this organizational principle can be observed in a relatively early stage along the visual processing hierarchy.

56.403 **Object Ambiguity Gates Access to Visual Awareness** Alisa M Braun[1](alisa.braun1@gmail.com), Timothy D Sweeny[2]; [1]University of Denver, Department of Psychology

Perception of objects often feels instantaneous. Object representation, however, is known to be an ongoing and possibly iterative process, one in which accumulated information is compared with current input until ambiguity about location or identity is resolved. According to this object-substitution account, not only discrimination, but awareness of an object should depend on how efficiently this disambiguation occurs. Objects that are less ambiguous should be more difficult to mask. We tested this hypothesis using a shape discrimination task. We asked observers to discriminate the aspect ratio of an ellipse shown for 20-msec within an array of circles. The target varied from extremely flat to extremely tall. Because aspect ratio is opponent-coded, the more elongated shapes should have been less ambiguous, not just in relevance to shape judgments, but also in their underlying representation. The target was surrounded by four dots that either offset simultaneously or lingered for 240-msec to induce masking, in both cases cuing the shape to be rated. On each trial, observers indicated the target shape's aspect-ratio and if it was visible. As expected, observers discriminated tall-vs-flat increasingly well when the targets had more extreme aspect ratios. More importantly, observers reported seeing elongated shapes more often than less extreme shapes. Crucially, this differential access to awareness only occurred on trials with masking. This is surprising since the shapes were otherwise identical in terms of attributes that should influence visibility (e.g., luminance, contrast, and area). These effects replicated across two additional experiments, which also ruled out alternative explanations such as proximity of the shapes to the masks. Our findings demonstrate that shapes with extreme aspect ratios are more readily available to awareness than shapes with ambiguous dimensionality. More generally, this work supports theories of object processing which suggest that ambiguity of visual representation gates access to awareness.

56.404 **Neural Substrates of Ensemble Perception** Michael L Epstein[1](mepstein@gradcenter.cuny.edu), Tatiana A Emmanouil[1,2]; [1]Program in Psychology, The Graduate Center, CUNY, [2]Department of Psychology, Baruch College, CUNY

Ensemble perception - the perception of numerous objects as a single group entity - is thought to be a basic visual process useful for surmounting known limitations of focused attention and individual object perception. While the speed of perception, resistance to distraction, and adaptation effects shown in behavioral studies suggest that ensemble perception may arise from processing in early visual areas, few studies have directly explored this by mapping activity specifically in striate and extrastriate regions of interest. We used a block design fMRI study to compare ensemble and individual object processing for different features using identical displays. Participants viewed two groups of phase shifting Gabor patches (750 ms stimulus duration, 8 trials per block) and were asked to compare either the average speed or orientation of the groups, or the individual speed or orientation of two cued individual objects, one from each group. These tasks were performed on separate runs and counterbalanced across participants. In order to distinguish task from difficulty effects, we varied the difficulty of each task on different blocks within runs. A region of interest analysis within visual cortex showed significantly increased activity in V2 and V3 for ensemble compared to individual feature processing. There were no main effects of feature (orientation, speed) or difficulty (easy, difficult) and no interactions within these areas. These results suggest that ensemble perception relies at least in part on distinct processing in extrastriate areas, and supports theories that ensemble perception constitutes a fundamental mechanism of visual information processing.

56.405 **Eccentricity drives developmental organization of human high-level visual cortex** Jesse Gomez[1](gomezj@stanford.edu), Michael Barnett[2], Kalanit Grill-Spector[1,3]; [1]Neuroscience Program, Stanford University School of Medicine, [2]Psychology Department, University of Pennsylvania, [3]Stanford Neurosciences Institute, Stanford University

Distributed responses to visual categories as well as category-selective regions in human ventral temporal cortex (VTC) are anatomically consistent across participants. This consistency has been theorized to be driven by basic organizational principles including eccentricity bias, size, curvilinearity, and animacy. Differentiating these theories requires examining the effects of learning a new visual category in childhood that differs from other categories along these dimensions. Here, we examined how learning Pokémon—a novel stimulus category from the popular Nintendo game that is foveal, linear, and animate—affects distributed responses in VTC. We scanned 11 subjects who, starting at age 5-7, began life-long visual experience with Pokémon, and 11 matched Pokémon-novice participants in a blocked fMRI experiment containing Pokémon, cartoons, animals, faces, bodies, cars, corridors, and words while performing an oddball task. Both groups were matched for experience with cartoons, and demonstrated similar cartoon decodability from mutlivoxel VTC responses (45±10%). Interestingly, we found significant decodability for Pokémon from VTC of experienced (60 ± 15%), but not novice subjects (22 ± 10%). In addition to normal face and corridor response patterns, experienced subjects demonstrated anatomically consistent and unique distributed patterns for Pokémon, with enhanced selectivity in the OTS. Using independent raters and software for determining image statistics, we quantified image properties of face, corridor, and Pokémon stimuli for animacy, size, curvilinearity, and eccentricity. Notably, the ordering of these 3 categories along these axes matched the ordering of distributed responses on cortex only for the eccentricity axis. Pokémon, faces and corridors were organized on a lateral-to-medial VTC axis that was coupled with the underlying eccentricity bias. Prolonged visual experience with a new object category during childhood sculpts distributed patterns in high-level visual cortex. Importantly, this study demonstrates eccentricity of the retinal image determines the development of the organization of distributed cortical responses in high-level visual cortex.

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56.406 **The Time Courses of Object Category and Location Representations in the Human Brain Depend on Clutter** Monika Graumann[1,2](monikag@zedat.fu-berlin.de), Caterina Ciuffi[1], Radoslaw M. Cichy[1,2]; [1]Department of Education and Psychology, Freie Universität Berlin, 14195 Berlin, Germany, [2]Berlin School of Mind and Brain, Berlin, Germany

The prevailing view of the ventral visual system is that object representations tolerant to particular viewing conditions such as location in the visual field emerge in high-level visual area IT, whereas object properties particular to the viewing situation are represented in low-level visual areas. Contrary to this theory, a recent study using single-cell electrophysiology and modelling in monkeys (Hong et al., 2016) observed that IT represents both object identity and location information, and that low-level visual areas might fail to represent object properties particular to the viewing situation when objects appear under real-world cluttered viewing conditions. Here, we investigated the processing of object location and category and its dependence on the nature of the background of the visual scene in the human brain using EEG and multivariate pattern classification. The rationale was that the latency with which object category and location representations emerge in the human brain indicate the processing stage in the ventral visual stream at which they emerge. In the experiment, participants (N=25) viewed object images from four different categories, in four different locations displayed in three background conditions (high-, low-, and no-clutter) (Fig. 1A). We found that representations of object category (Fig 1B) and object location (Fig. 1C) emerged later in time when objects were presented on cluttered backgrounds (20 ms later for category, and 70 ms later for location). Further analysis comparing the temporal dynamics with which location representations emerged in the clutter- vs. no-clutter condition revealed similar representations shifted in time, rather than different representations (Fig. 1D). Together, our findings show that contrary to the prevailing theory of object recognition in cortex, under real-world viewing conditions not only category, but also object location is represented in late processing stages.

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56.407 **The neural encoding of object hardness** Li Guo[1](lguo15@jhu.edu), Alissa Stafford[1], Susan Courtney[1], Jason Fischer[1]; [1]Department of Psychological and Brain Sciences, The Johns Hopkins University

In daily life, we continually form intuitions about how the physical world will behave. We "see" that a bulky door will require a hard push to open, or a coffee cup is precariously placed and may fall. To form these predictions about physical behavior, we must at the same time estimate the relevant physical properties of objects and surfaces in the scene (e.g., their hardness, smoothness, and density). Do these two facets of physical scene understanding – representing physical properties and mentally simulating physical dynamics – rely on common neural machinery? Here, we sought to identify brain regions that encode object hardness – a key determinant of behavior in physical interactions – and test whether they coincide with brain regions recruited by physical prediction tasks. In an fMRI experiment, we presented participants with images of everyday objects and tasked them with judging the hardness of each object. In separate scanning runs, we localized functional regions of interest for brain areas engaged when people observe and predict the unfolding of physical events (the "neural physics engine"; Fischer et al., 2016). Within the neural physics engine ROIs, a multivariate pattern analyses revealed parametric encoding of object hardness: the pattern of BOLD response varied smoothly and systematically with incremental changes in hardness. By contrast, we found no such encoding of hardness information in independently localized ventral object-selective regions. A searchlight analysis verified the robust encoding of object hardness within areas corresponding to the neural physics engine, but also uncovered a region in ventral premotor cortex that reliably displayed the most precise encoding of object hardness in the brain. This ventral premotor region may play a complementary role in physical scene understanding to other regions in the neural physics engine, inferring information about physical properties to be used in mental simulations of physical behavior.

56.408 **Using HD-EEG to Explore Spatiotemporal Representations of Object Categories in Visual Cortex** Gennadiy Gurariy[1](genaxl@yahoo.com), Jacqueline C. Snow[1], Ryan E.B. Mruczek[2], Matthew R. Johnson[3], James Mardock[1], Gideon P. Caplovitz[1]; [1]University of Nevada, Reno, [2]Worcester State University, [3]University of Nebraska, Lincoln

Traditionally, the dorsal and ventral pathways of the visual system were thought to be involved in fundamentally different neural processes: object identification & object manipulation, respectively. However, in light of a growing body of literature, these traditional distinctions are gradually being redefined. Here, we investigate the spatiotemporal representations of object categories across the two pathways using High-Density EEG. In two experiments, participants viewed images from four object categories: animate (birds & insects) and inanimate (tools & graspable objects). A third experiment controlled for shape confounds commonly observed when comparing tools to other object categories. To explore temporal representations of category information, we employed time-resolved univariate and multivariate pattern analyses (MVPA) on the EEG time series data at the exemplar, subordinate and superordinate level. This was done at both the electrode level and in dipole source space within two broadly defined regions of interest: one encompassing ventral-temporal cortex (Ventral Stream) and the other encompassing posterior parietal cortex (Dorsal Stream). Our results demonstrate that shape, exemplar and categorical object representations can be detected in the EEG signal within 100ms of stimulus onset using a variety of analytic approaches. Specifically, we note that the following categories can be successfully decoded within the two pathways: (1) Shape (elongated vs. stubby) (2) Animate object categories (bird vs. insect), (3) Inanimate object categories (tool vs. graspable object), even when the elongation confound is controlled for between the stimuli. Of particular interest, we observe striking similarities between results obtained in both the Ventral-Stream and Dorsal-Stream ROIs. Together, these findings provide insight into the spatiotemporal dynamics of object representation and contribute to a growing literature that has begun to redefine the traditional role of the dorsal pathway in visual processing.

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56.409 **Shape changes in global properties weaken the innate defensive responses to visual threats of mice** Yan Huang[1](y-huangrj@foxmail.com), Lei Li[1], Kun Dong[2], Yundan Liao[3], Xianglian Jia[1], Hongsi Tang[1], Liping Wang[1]; [1]the Brain Cognition and Brain Disease Institute (BCBDI), Shenzhen Institutes of Advanced Technology, Chinese Academy of Sciences, Shenzhen 518055, China, [2]School of Basic Medical Sciences, Nanjing Medical University, Nanjing, Jiangsu 210029, China, [3]Xiangya School of Medicine, Central South University, Changsha, Hunan Province, 410013, China

Accumulating behavioral evidence suggests that the processing of global topological properties serves as the starting point of object representation formation. Evidence from human brain imaging studies suggests that the global topological perception may be processed through a fast subcortical pathway, stemming from the superior colliculus (SC) to the pulvinar and then to the amygdala. Neural circuitry studies in mice demonstrate that SC is essential for the defensive responses to overhead looming stimuli, an expanding black disk in the upper-field, which is said to mimic an aerial predator. Here we hypothesize that the topological change inserted briefly into the continuous looming stimuli would impair the object continuity, and thus alter the defensive behaviors of mice when faced with the 'impaired' looming stimuli. Here, we conduct a series of behavioral experiments on mice to test the influence of several types of shape changes, including global and local properties, on mice's defensive behavioral outputs. We find that the flight latency of mice was significantly prolonged when the 80-ms topologically-different shape was inserted into the looming stimuli, while other non-topological shape changes showed no effect on the flight latency. Moreover, we find that the c-fos activation in the intermediate and deep layers of the SC (InWh and DpG) decreased in the topological-change group when compared with the normal looming stimuli one. In conclusion, our findings suggest that topological changes weaken mice's fear response to the looming stimuli, and the neurons in the SC are involved in both topological differences detection and innate visual dangerous information processing.

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56.410 **Typical real-world locations facilitate object processing** Daniel Kaiser[1](danielkaiser.net@gmail.com), Merle M Moeskops[1], Radoslaw M Cichy[1]; [1]Freie Universität Berlin

The object content of most real-world scenes is structured: It is characterized both by the types of individual objects (e.g., a living room typically consists of a sofa, a table, a lamp and a carpet) and by their locations (e.g., a carpet typically lies on the floor, whereas a lamp is hanging from the ceiling). The repeated co-occurrence of specific object types and locations prompts the hypothesis that object processing should be most efficient when the objects appear in their typical locations (e.g., a lamp in the upper visual field), relative to atypical locations (e.g., a lamp in the lower visual field). Here, we present behavioral and neural data that provide converging support for this hypothesis. In a continuous flash suppression paradigm, observers were faster in detecting an object under conditions of inter-ocular suppression when the object was shown in its typical location. This benefit in behavioral performance suggests a processing enhancement for typically positioned objects, allowing them to more efficiently compete in inter-ocular suppression. Using multivariate classification of both fMRI and EEG data, we spatiotemporally characterize this processing enhancement on a neural level: Representations in object-selective regions of the lateral occipital cortex (fMRI) and 140 ms after stimulus onset (EEG) allow for increased decoding of object information if the object is shown in its typical, relative to an atypical, location. Together, these data suggest that objects presented in typical locations gain a processing advantage during early, presumably bottom-up, stages of object processing. The early sensitivity for positional regularities may be highly beneficial for object detection in naturalistic environments where multiple, but regularly positioned, objects need to be processed.

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56.411 **Serial Dependence on a Large Scale** Mauro Manassi[1](mauro.manassi@berkeley.edu), Yuki Murai[1,2], David Whitney[1]; [1]University of California, Berkeley, Department of Psychology, Berkeley, CA, USA, [2]Japan Society for the Promotion of Science

Despite the noisy and ever-changing visual world, our visual experience appears remarkably stable over time. Recent research indicates that our percepts, such as orientation, are biased towards previous percepts (Fisher & Whitney, 2014). Based on this and other recent results, serial dependence was proposed as a mechanism to facilitate perceptual stability, compensating for variability in visual input. Whereas serial dependence was shown to occur with a variety of stimuli, the underlying mechanism(s) and determining factors are still unknown. Here, we investigated individual differences in serial dependence on a larger scale, with a sample size of 125 naive participants. Observers were presented with a sequence of oriented Gabors and were asked to adjust the orientation of a bar to match each Gabor's orientation. Positive serial dependence had an average half-peak strength of 1.6°. Serial dependence, in these participants, remained robust across demographic differences (e.g. gender and age) and levels of task difficulty. Interestingly, serial dependence was stronger for low contrast Gabors compared to medium and high contrast Gabors and serial dependence was more consistent for low contrast Gabors (100% of participants, 4°) versus high Contrast (78% of participants, 1.8°). Serial dependence was also stronger for oblique angles compared to cardinal angles (4° vs. 0.5°) and present in a larger number of participants (89% vs 62%). Taken together, our results show serial dependence is a stable and consistent perceptual effect across observers, although it can be modulated by multiple factors. These results further reinforce the idea of serial dependence as a mechanism to promote perceptual stability in everyday life.

56.412 **The effect of expertise upon behavioral and neural representational spaces** Hans P Op de Beeck[1](hans.opdebeeck@psy.kuleuven.be), Farah Martens[1]; [1]Brain & Cognition, KU Leuven, Belgium

When people become an expert in a particular domain, they process objects of expertise in a different manner. Previous neuroimaging studies have demonstrated how this expertise alters brain activity by comparing objects of expertise with other objects (e.g., Gauthier et al., 2000, Nature Neuroscience; Harel et al., 2010, Cerebral Cortex). However, everyone knows whether an image depicts a bird or a car. In contrast, only a bird expert can tell apart a great-tailed from a boat-tailed grackle. Here we focus upon the neural basis of expertise at this detailed level by comparing the similarities and differences of the representational spaces of birds between 20 ornithologists and 20 control participants. We scanned subjects with functional magnetic resonance imaging while presenting images of 24 different bird types. The image set was organized in 8 triplets, which each contained two birds that belonged to the same species but were visually different (e.g. male and female) and one bird that resembled one of the other two birds but belonged to a different species. As such, the triplets dissociated species-level semantics from visual similarity. Behaviorally, ornithologists showed more within-group consistency in subjective similarity ratings compared to controls. In addition, the ornithologists showed a sensitivity to the dissociation between species and visual appearance when rating semantic similarity. A neural representational similarity analysis analyzed the multi-voxel patterns in low-level visual cortex (LVC), high-level visual cortex (HVC), and prefrontal cortex (PFC). In PFC, the neural patterns distinguished bird types more reliably in ornithologists than in controls. In addition, the similarity structure of the neural patterns was more shared between ornithologists than between controls, in particular in HVC and in PFC. Overall, the fMRI findings suggest that expertise results in an overall expansion of the neural representational space of objects of expertise, but not in a qualitatively different organization.

56.413 **Using Neural Distance to Predict Reaction Time for Categorizing Animacy, Shape, and Abstract Properties** J. Brendan W Ritchie[1](brendan.ritchie@kuleuven.be), Hans P Op de Beeck[1]; [1]Laboratory of Biological Psychology, Brain and Cognition, KU Leuven

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Previous research has shown that distance to a decision boundary through neural activation space can be used to predict reaction times (RT) on animacy categorization tasks (Ritchie and Carlson, 2016). More specifically, it has been found that this relationship is driven by animate, but not inanimate exemplars. However it has yet to be explored how this relationship is impacted by target visual features, or whether the RT-distance relationship holds for other categorization tasks. Here we tested whether this asymmetry still held when animate and inanimate stimuli were balanced along an orthogonal shape dimension (Bracci and Op de Beeck, 2016). We also tested whether the same RT-distance relationship held when observers performed a shape categorization task, and an abstract object location categorization task that criss-crossed the dimensions of animacy and shape. Using human fMRI (N = 15), and focusing on shape and object category-selective regions of visual cortex, we correlated neural distance from a classifier decision boundary with observer RTs on the animacy, shape, and location tasks. In line with previous findings we found a negative correlation between RT and distance for the animacy task, and also the shape task, but the same relationship was not observed for the location task. This negative finding suggests that the neural coding for these other properties of objects might depend on a different mapping between activation space and categorization behavior.

56.415 **Visual Scenes Prime Associated Novel Objects as a Function of Prime-Target Delay, Temporal Expectancy, and Hemispheric Lateralization** Cybelle M Smith[1](cmsmit13@illinois.edu), Kara D Federmeier[1]; [1]Department of Psychology, University of Illinois Urbana-Champaign

When and how does the brain make use of contextual information to facilitate visual object perception? We recorded EEG while participants (N=72) learned paired associations between scenes and novel objects from novel object categories. At test, scenes were presented and, after a delay, a matching or mismatching object appeared. We previously showed that varying the amount of scene preview time at test affects the time course of predictive facilitation for the object. Long (2500ms), vs. short (200ms), preparation times induced a latency advance in the LPC and the appearance of a fronto-central N300 match effect. We (N=36) replicated these findings using a parametric, within-subjects design, by randomly varying the scene preview duration (0-2500ms). LPC match effect amplitude increased and latency decreased with increased preparation time, consistent with earlier results. However, graded effects of match (assessed using mismatching objects that were similar to a match, both visually and in terms of their distribution across contexts) were attenuated or absent, suggesting a role for temporal expectation in graded contextual prediction. We next used lateralized presentation with a long scene preview (2500ms; N=36) to explore whether the cerebral hemispheres differentially contribute to visual object prediction. Left visual field/Right Hemisphere (lvf/RH) presentation resulted in an earlier facilitation for the match condition relative to either mismatch type at prefrontal sites compared with right visual field / Left Hemisphere (rvf/LH) presentation. However, rvf/LH but not lvf/RH presentation induced sensitivity to close vs. 'impossible' mismatches at fronto-central sites (onset ~350ms). Findings suggest knowing when and where a visual object will appear helps us to anticipate it, and are consistent with the right hemisphere preactivating a more specific visual representation of the match than the left.

Acknowledgement: NIA grant AG2630 and James S. McDonnell foundation award to KDF, Neuroengineering IGERT and NSF-GRFP DGE-1144245 to CMS

56.416 **Transcranial direct current stimulation (tDCS) on the left dorsolateral prefrontal cortex (lDLPFC) selectively modulates our sense of beauty** Kuri Takahashi[1], Yuko Yotsumoto[1]; [1]Department of Life Sciences, The University of Tokyo

Recent neuroimaging studies have revealed the involvement of the prefrontal cortex in the process of making an aesthetic judgment. One study reported that transcranial direct current stimulation (tDCS) of the left dorsolateral prefrontal cortex (lDLPFC) led to the significant enhancement of subjects' aesthetic judgment of visual images. We tested whether subjects' aesthetic judgments of visual and sensuous stimuli can be modulated by applying tDCS on the lDLPFC with the same parameters (2 mA, 20 min) used in a previous study. Sixteen subjects underwent the stimulation and sham conditions. We also measured subjects' feelings of pleasure, which has been reported to correlate with the feeling of beauty. We used six images from the International Affective Picture System (IAPS) with high valence ratings, and six IAPS images with middle valence ratings for visual stimuli; candies with six different kinds of flavors for gustatory stimuli, and stuffed animals with different kinds of textures for tactile stimuli (Brielmann & Pelli, 2017). Subjects rated their feelings of pleasure (1–10) during 30 s of stimulus exposure and in the following 60 s. At the end, they were asked to rate the beauty of the stimuli (0–4). The results showed that only the beauty of visual stimuli tended to receive lower ratings after stimulation. Bayes factor, an indicator of which among two competing models is a better data predictor, supported the decrease in beauty ratings through tDCS with high-valence and middle-valence IAPS images 1.4 and 1.9 times, respectively, more than the model that predicted that tDCS had no effect on rating. The ineffectiveness of tDCS on pleasure was 2.6 times higher than the model that tDCS had an effect on pleasure. Overall, our study suggests that effect of tDCS may be limited to certain modalities and that judgments of feelings of beauty and pleasure might involve independent processes.

Acknowledgement: KAKENHI-16H03749, 17K18693, 25119003

56.417 **Decoding face- and house-associated eye-movement patterns in FFA and PPA** Lihui Wang[1,2], Florian Baumgartner[1], Michael Hanke[1,2], Stefan Pollmann[1,2]; [1]Department of Experimental Psychology, Otto-von-Guericke University, Magdeburg, [2]Center for Behavioral Brain Sciences, Magdeburg, Germany

The functional topography of the motor cortex represents natural movement patterns (Aflalo and Graziano, 2011). Here we asked if such movement patterns are already represented at the beginning of the perception-action cycle in that visual areas represent the motor programs that are typically used in looking at specific visual stimuli. Specifically, we investigated whether the fusiform face area (FFA) and the parahippocampal place area (PPA) contain a representation of gaze patterns that are used when looking at faces or houses. For this purpose, we instructed observers to follow a dot presented on a uniform background. In Experiment 1 and 2, the dot's movement represented 3000ms of the gaze path acquired from an independent observer while looking at face or house pictures. Results from Experiment 1 showed that face- and house-associated gaze patterns could be discriminated by multivariate pattern analysis in FFA and PPA. This discrimination was still observed when gaze dispersion differences were controlled in Experiment 2. To control differences in the physical properties of the visual stimuli, in Experiment 3, the dot's movement represented the first 600ms of the gaze path acquired from either the current observer or from another observer of the sample (who would receive the first observer's gaze paths as the "other" path). We found that only the own face- and house-associated gaze patterns could be discriminated, underlining the individual nature of gaze patterns and ruling out stimulus differences as confounds. The discrimination of the observer's gaze patterns was specific to FFA and PPA, but was not observed in early visual areas (V1 - V5/MT). Moreover, the individual decoding accuracy in FFA was correlated with the accuracy in following the gaze patterns. These findings indicate that FFA and PPA represent complex gaze patterns that are used to explore the visual object categories represented in these areas.

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56.418 **Neural Representation of Spatial Layout and Relational Information among Multiple Objects** Ruosi Wang[1](ruosiwang@fas.harvard.edu), Yaoda Xu[1]; [1]Psychology Department, Harvard University

How multiple distinctive objects may be represented in the human brain is largely unknown. A multi-object display can be characterized by three features: The identities of the objects, the global layout of the objects, and the precise relationship between adjacent objects. Using fMRI MVPA, here we investigated how these features of a multi-object display may be represented in the human brain by examining responses from topographically defined early visual areas (V1-V4), object processing regions in higher ventral regions (LO and pFs) and parietal regions (inferior IPS and superior IPS). The experimental displays were created by manipulating the locations of three artificial objects or three novel shapes on a donut-shaped background. In order to examine layout representation independent of location representation, while keeping layout the same, the three

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objects rotated around the donut within a block of trials. We also included a control condition to assess the contribution of spatial envelope to spatial layout representation. Participants viewed the displays and performed an orthogonal size change detection task. In V4 and pFs, we observed successful object identity decoding. In LO, we observed not only object identity decoding, but also decoding for the global layout of the objects and the precise pairing between objects. Importantly, the global layout decoded in LO could not be attributed to the representation of the spatial envelope of the multi-object display. In contrast, spatial envelope contributed significantly to global layout decoding in inferior IPS and superior IPS. These results show that all three features characterizing a multi-object display are represented in LO, suggesting that this brain region likely plays an important role mediating the perception and representation of multi-object displays.

Acknowledgement: NIH Shared instrumentation grant (S10OD020039)

Object Recognition: Reading and other

Tuesday, May 22, 2:45 - 6:45 pm, Pavilion

56.419 The fine-grained sub-millisecond objective and subjective psychophysics of stimulus representation

Dalila Achoui[1](dalila.achoui@gmail.com), Axel Cleeremans[1]; [1]Center for research in Cognition and Neurosciences, Université Libre de Bruxelles

A custom designed LCD tachistoscope enabled us to display stimuli in the sub-millisecond range with very high precision. These extremely brief presentation times allow us, for the first time, to zoom in on the psychophysics between two subsequent levels of stimulus representation. Moreover, a precision of ~5 microseconds allows us to individually adjust and control the level of representation at which the stimulus is being perceived by each specific participant. We were interested in both the objective and subjective psychophysics between representational levels. Particularly the question of whether subjective perception shows a similar psychophysical curve as objective performance or whether it increases with a step-like function between each hierarchical level of stimulus representation. We first obtained the perceptual thresholds for a low-level detection task (absent vs. present) and a higher-level discrimination task (object A vs. B) over a range of 300 - 1125 microseconds. We then used the detection threshold in a subjective perception task in which participants indicated in which of two time intervals the stimulus was most visible. Crucially, the two intervals different slightly in duration but were both centered around their individual threshold. Importantly, by setting the threshold individually we were able to ensure that participants perceived the stimulus only at the low-level representation ("An object is present"), but were not able to perceive any other stimulus features. The average perceptual thresholds were as low as 550 microseconds for detection, and 790 microseconds for discrimination. Participants performed above chance on the subjective task, suggesting that, independently of the level of representation, subjective perception improves with stimulus duration. Our tachistoscope allowed us to use such brief stimulus durations that we were able to obtain distinct psychophysical curves for two subsequent levels in the visual hierarchy. Moreover, we showed that subjective perception increases independently of level of representation.

56.420 How does reading expertise influence letter representations in the brain? An fMRI study

Aakash Agrawal[1](aakash@iisc.ac.in), K.V.S. Hari[2], S. P. Arun[3]; [1]Center for Biosystems Science and Engineering,Indian Institute of Science, [2]Department of Electrical Communication Engineering, Indian Institute of Science, [3]Center for Neuroscience, Indian Institute of Science

Learning to read results in the formation of the Visual Word Form Area (VWFA) within the visual cortex, but precisely how letter shape representations in VWFA and other visual regions in the brain change with reading is not well understood. We investigated these issues by selecting two Southern Indian languages, Telugu and Malayalam, which have entirely distinct scripts with relatively little overlap among readers. We identified two groups of subjects: one fluent in reading Telugu but not Malayalam, and the other fluent in Malayalam but not Telugu. Using fMRI, we measured the brain activity while subjects viewed Telugu and Malayalam words in a 1-back task. Our main findings are as follows: (1) BOLD activation in hV4, VWFA and Middle Temporal Gyrus (MTG) was larger for familiar letters compared to unfamiliar letters but smaller in the Lateral Occipital Complex (LOC). Both findings are double dissociations, thereby eliminating any confound due to subject group or letter shape. (2) The location of the VWFA peak was systematically different for Telugu and Malayalam letters; (3) VWFA voxel activations were correlated more strongly with MTG for native letters compared to non-native letters; (4) VWFA activations were positively correlated with language fluency across subjects. Taken together, our results suggest that reading expertise alters letter shape representations throughout the visual cortex. Furthermore, VWFA appears to be an intermediate stage of the reading network that integrates visual and auditory letter representations.

Acknowledgement: Wellcome DBT India Alliance and DBT-IISc partnership programme

56.421 Visual word classification and image reconstruction from EEG-based time-domain and frequency-domain features

Shouyu Ling[1](shouyu.ling@mail.utoronto.ca), Andy C.H. Lee[1,2], Blair C. Armstrong[1,3], Adrian Nestor[1]; [1]Department of Psychology at Scarborough, University of Toronto, Toronto, Ontario, Canada, [2]Rotman Research Institute, Baycrest Centre, Toronto, Ontario, Canada, [3]BCBL. Basque Center on Cognition, Brain, and Language

An increasing body of work has established the ability of neuroimaging data to support image reconstruction for single characters (e.g., letters or digits). Here, we classify and, then, reconstruct the appearance of whole words from electroencephalography (EEG) data with the aid of time-domain and frequency-domain features. To this aim, we recorded EEG signals from 14 right-handed adult participants while they viewed images of high-frequency concrete nouns with a consonant-vowel-consonant structure. Specifically, participants performed a one-back image task while viewing 80 unique words (repeated 96 times across 32 blocks). Time-domain features were provided by signal amplitudes up to 900ms after stimulus onset for 64 channels. Further, we extracted a large collection of frequency-domain features including the magnitude-squared coherence, the cross power spectral density phase and the continuous wavelet pseudopower for multiple frequency bands. Such features were then used for the purpose of pairwise word classification, word space estimation, visual feature synthesis and image reconstruction. Importantly, we found that EEG-based classification and reconstruction accuracies were well above chance. However, time-domain features outperformed systematically their frequency-domain counterparts. More specifically, we found that: (i) the most diagnostic features in the time domain were concentrated around the N170 ERP component at bilateral occipitotemporal (OT) channels; (ii) in the frequency domain, the most valuable information came from sums of continuous wavelet pseudopower in the mid and high beta bands across OT electrodes, consistent with the implication of these bands in visual perception and attention, and (iii) complementary information was widely distributed and could be used to further boost performance (e.g., signal amplitudes around N250 and theta band features). Thus, our results highlight the diverse sources of information associated with word processing as reflected by the EEG signal. More generally, they demonstrate the feasibility of whole-word image reconstruction from neuroimaging data.

Acknowledgement: NSERC

56.422 Is the critical print size for reading linked to letter recognition?

Steve Mansfield[1](mansfijs@plattsburgh.edu), Taylor R. West[1], Zierra Dean[1]; [1]Psychology, SUNY College at Plattsburgh

Rationale: The critical print size for reading is the smallest print size that can be read at the reader's maximum reading speed. We have explored whether the critical print size is related to the size at which letter recognition starts to become difficult. In a pilot study of recognition errors with blurred Times-Roman letters, we noted that some letters [d, f, g, j, k, m, p, q, v, w, and y] remain easy to identify at more severe levels of blur than others. We hypothesize that sentences containing more of these easy letters ought to have a smaller critical print size than sentences containing fewer easy letters. Method: We created two sets of computer-generated, 60-character, MNREAD sentences that contained either many (M=14.3, SD=0.81) or few (M=4.7, SD=0.56) easy letters. We used computer versions of the MNREAD chart with 12 print sizes spanning +0.8 to –0.3 logMAR to measure reading-speed versus print-size curves from 36 participants. Each participant read five versions of the chart for each sentence condi-

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tion. Results: The critical print size (estimated from curve fits to the reading-speed versus print-size data) for sentences containing many easy letters was 0.034 logMAR (i.e., 8.1%) smaller than the critical print size for sentences containing few easy letters (95% CI [0.027, 0.040]). Conclusion: This finding is consistent with the critical print size being linked to letter recognition. We propose that, with large print, letter recognition is accurate and reading is fast. But as print size is reduced, letter recognition becomes error prone and the reader is required to infer the identity of words that contain misidentified letters — this produces slower reading speeds.

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56.423 **Test-Retest Reliability of the quick Reading method** Timothy G Shepard[1](timmyshepard@gmail.com), Zhong-Lin Lu[2], Deyue Yu[1]; [1]College of Optometry, Ohio State University, [2]Psychology, Ohio State University

We recently introduced quick Reading, a novel, Bayesian adaptive method, to measure the reading speed vs print size function (Shepard et al, ARVO 2017; Lu et al, ARVO 2017). The precision of the method was assessed with the 68.2% half-width of credible interval (HWCI) of the estimated function from a single run of the procedure. The purpose of this study is to evaluate the test-retest reliability of the quick Reading method. Ten native English speakers (five well-practiced "experts" and five naïve observers) participated in a one-session experiment which contained five quick Reading blocks of 50 trials each in the periphery. We obtained one estimated reading function in each of the five blocks. Four metrics were computed to evaluate the test-retest reliability of the method. 1) Averaged across blocks, print sizes and observers, the SD was 0.03 and 0.07 log10 units for the expert and naïve observers, respectively. 2) The average HWCI of the estimated reading speed was 0.022 and 0.024 log10 units in the expert and naïve groups, respectively. 3) Because the reading speeds on each single reading function are constrained by its functional form, we applied a sampling procedure (Hou et al, 2016) to remove such constraint in assessing correlations between repeated measures of the reading function. The correlation coefficients were 0.98 for the expert group and 0.96 for the naïve group. 4) The area under the reading curve (AURC) was calculated. A one-way repeated measures ANOVA was conducted to examine changes in the AURC over the five repeated tests. We found no significant change in either group (expert: $F(4,16) = 1.164$, $p=0.363$; naïve: $F(4,16) = 2.371$, $p=0.096$.) Overall, we showed that the quick Reading method can achieve very high precision with 50 trials in peripheral vision.

Acknowledgement: R01EY025658

56.424 **Left-lateralized interference of letter recognition on mirror-invariant object recognition** Lars Strother[1](lars@unr.edu), Matthew T. Harrison[1]; [1]University of Nevada, Reno

Many letters do not exhibit mirror invariance to the same degree as objects. In the case of "reversible" letters (e.g., 'b' and 'd'), mirror reflection is the sole differentiating factor. A negative priming study by Borst et al. (2014) showed that visual recognition of reversible letters interferes with subsequent object recognition. Findings from other behavioral and neuroimaging studies raise the possibility that this conflict is due to language-related visual processing in left ventral occipitotemporal cortex. We tested this possibility by adapting the method of Borst et al. to a divided visual field paradigm, which allowed us to test whether or not negative priming of mirrored letters on mirrored objects is lateralized or not. Observers performed a letter discrimination task, immediately followed by an object discrimination task performed in either the right or the left visual hemifield. In agreement with Borst et al., we found that suppression of mirror invariance during letter recognition interfered with its recovery during the subsequent object recognition task, but only for mirrored objects viewed in the right visual hemifield. Our results show a direct relationship between mirror invariant object recognition, its suppression, and language-related visual processing in the left hemisphere.

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56.425 **Visual and Motor Experiences of Handwriting Independently Contribute to Gains in Visual Recognition** Sophia Vinci-Booher[1](svincibo@indiana.edu), Neha Sehgal[1], Karin James[1]; [1]Department of Psychological & Brain Sciences, College of Arts & Sciences, Indiana University

Handwriting, as a learning method, has been shown to be particularly effective at increasing letter recognition, yet we do not know why handwriting has this effect. We hypothesized that the coordination between the motor and visual experiences that is inherent to the act of producing a letter by hand contributes to the development of dynamic representations for letters, representations of the letter unfolding, that play a role in letter recognition. One hundred college-aged participants were taught novel symbols in particular stroke orders. Training occurred within-participants and included writing with ink, writing without ink, watching an experimenter write with ink, and watching an experimenter write without ink. Participants were then shown the learned symbols as well as unlearned symbols unfolding, stroke-by-stroke, in both learned and unlearned stroke orders, and asked to perform a recognition judgment. We predicted that recognition would be most efficient for symbols presented in the learned stroke order and, further, that writing with ink would result in the most efficient recognition. We found that participants more readily recognized symbols when presented in learned stroke orders, but found that the visual experiences and motor experiences that occurred through handwriting contributed independently to the formation of these dynamic representations. Our results indicate that one way that handwriting increases letter recognition is through the formation of dynamic representations for letters and, surprisingly, that these dynamic representations can be established by experiencing the motor action without the visual percept, and vice versa. Handwritings' effectiveness may, therefore, reside in the fact that handwriting provides both motor and visual experiences, each of which would be effective on their own.

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56.426 **Anterior Fusiform Naming Area: a Patch at the Anterior Tip of the Fusiform Causally Linked to Reading and Language** Michael J Ward[1](mjw108@pitt.edu), Matthew Boring[2,3], Edward Silson[4], Mark Richardson[1,3], Chris Baker[4], Julie Fiez[5,6], Avniel Ghuman[1,3]; [1]Department of Neurological Surgery, University of Pittsburgh, [2]Center for Neuroscience, University of Pittsburgh, [3]Center for the Neural Basis of Cognition, Carnegie Mellon University and University of Pittsburgh, [4]Section on Learning and Plasticity, Laboratory of Brain and Cognition, National Institute of Mental Health, [5]Learning Research and Development Center, University of Pittsburgh, [6]Department of Psychology, University of Pittsburgh

The role of the ventral anterior temporal lobe (ATL) in language processing remains unclear. In particular, electrical disruption of much of the ventral temporal cortex has been shown to effect naming. Here, we present intracranial electroencephalography (iEEG), direct cortical stimulation, 7T fMRI, and neuropsychology results that describe a new word sensitive region at the anterior tip of the fusiform gyrus, which we dub the anterior fusiform naming area. In 4 epilepsy patients undergoing iEEG, electrodes in the left anterior fusiform exhibited word sensitivity over five other categories of visual stimuli. Direct cortical stimulation was administered to one patient, disrupting word reading when applied to the word sensitive electrode. The word sensitivity demonstrated in these studies is consistent with 7T fMRI findings of sensitivity to words versus objects in the anterior fusiform. Additionally, neuropsychological testing performed with 2 of 2 patients following left ATL resection that included this region revealed surface dyslexia, which is characterized by "over-regularization" of exception words (e.g., "sew" read as "sue"). In contrast, 1 of 1 patient with an equivalent right hemisphere resection tested with normal reading ability. Anterior temporal lobectomy is standard surgical treatment for intractable epilepsy, and to our knowledge, these are the first reported cases of surface dyslexia following the procedure. Given that surface dyslexia is a robust early symptom in the progression of neurodegenerative diseases of the ATL, these results emphasize the role of this region in reading and language processing and strongly suggest the presence of a word sensitive patch at the anterior tip of the fusiform. We hypoth-

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esize that this patch is critical for reading exception words that must be processed as unique entities, paralleling other findings that describe a role for ATL regions in processing other types of unique entities, such as famous faces and landmarks.

56.427 Probing the serial bottleneck in visual word recognition Alex L White[1](alexlw@uw.edu), John Palmer[1], Geoffrey M Boynton[1]; [1]Department of Psychology, University of Washington

Is it possible to recognize two words at once? This question relates to the more general investigation of divided visual attention, and to a fierce debate about whether multiple words are processed serially or in parallel during natural reading. We recently found evidence of a serial bottleneck in a semantic categorization task (White, Palmer & Boynton, Psychological Science, in press). In that study, observers viewed masked pairs of words and either focused their attention to judge one word (single-task condition) or attempted to divide their attention to judge both words independently (dual-task condition). Accuracy was so much worse in the dual-task condition that it supported an all-or-none serial model: observer could distinguish the semantic category of only one of the words and had to guess about the other. In this presentation, we delve further into the data and present new experiments to investigate whether parallel processing is possible in some circumstances. Specifically, we first examine the effects of word length and lexical frequency on semantic categorization. Is parallel processing possible for two short (3-4 letter) words, or for two high-frequency words? The answer is no: accuracy in the single-task condition was affected by length and frequency, but dual-task accuracy was always so low that it supported the serial model. We also present a new lexical decision experiment that was similar except the task was to distinguish real words from pseudowords. If the serial bottleneck lies in high-level semantic processing, then this task should show less of a dual-task deficit and evidence of parallel processing. Alternatively, if the bottleneck applies to any kind of lexical processing, then this task should also show a severe dual-task deficit. Preliminary evidence indicates that even in the lexical decision task, a serial bottleneck prevents more than one word from being processed at a time.

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56.428 Reading with Letter Transpositions in Central and Peripheral Vision Ying-Zi Xiong[1](yingzi@umn.edu), Chenyue Qiao[1], Gordon E. Legge[1]; [1]Department of Psychology, University of Minnesota

Purpose Letter transpositions (the reversal of pairs of adjacent letters) result in slower reading speed (Rayner et al, psychol Sci 2006). The reduction is greatest for initial letters ('turtle' to 'utrtle'), intermediate for ending letters ('turtel'), and least for middle letters ('tutrle'). Of relevance to some forms of low vision, letter transpositions might have less impact for reading with peripheral vision because of increased spatial uncertainty for letter positions in the periphery. Our study investigated how letter transpositions affect reading performance (speed, critical print size and reading acuity) in both central and peripheral vision. Method Sixteen normally-sighted native English speakers performed computer-based versions of the MNRead test in central vision, and a rapid serial visual presentation (RSVP) test of reading speed in both central and peripheral (10° lower field) vision. The tests included separate blocks with letter transpositions in initial (INIT), middle (MID) and end (END) positions. Approximately 40% of the words in each sentence had a transposition. Results For MNREAD testing in central vision, there were significant reductions in maximum reading speed for all three transposition conditions—INIT (25.6±2.4%), MID (9.0±2.5%) and END (22.0±3.5%). Critical print size (CPS) was only affected in the INIT condition by 0.16±0.05 logMAR. Reading acuity was not affected by the transposition conditions. For RSVP reading in central vision, there were significant reductions in reading speed for all three conditions—INIT (40.8±5.4%), MID (22.8±6.1%) and END (27.1±5.4%). The RSVP speed reduction in peripheral vision was significantly less, and only the INIT condition showed a significant drop of reading speed by 20.2±9.5%. Conclusion Our results in central vision confirmed Rayner's finding that letter transpositions reduce reading speed, but only weak effects were found for CPS and reading acuity. Peripheral reading is less affected than foveal reading by transpositions, possibly due to higher spatial uncertainty in the periphery.

Acknowledgement: NIH EY002934

56.429 Letter recognition in different fonts Deyue Yu[1](yu.858@osu.edu), Emily Watson[1]; [1]College of Optometry, Ohio State University

Reading performance can vary markedly with font. Mansfield and colleagues (1996) showed that people with low vision read faster in Courier than in Times, especially at small print sizes. Here, we assess single-letter recognition in different fonts, and explore whether the font effect starts to emerge at the stage of letter recognition. Twenty-five normally-sighted young adults identified single letters at 10deg eccentricity left and right of the fixation. Three fonts were tested: Courier (monospaced, serif font), Times New Roman (proportionally spaced, serif font) and Century Gothic (proportionally spaced, sans-serif font). A letter size of 0.4° (defined by x-height) was used. For a given font, each of the 26 lowercase English letters was presented ten times at each testing position. The data were collapsed across the two testing positions and 25 subjects (a total of 500 trials per letter) to construct a confusion matrix for each font. We found that accuracy of letter recognition was always highest for Courier (82%), intermediate for Times New Roman (75%), and lowest for Century Gothic (71%). The pattern of confusions also varied with font. The comparisons among the confusion matrices provided valuable information on what and how letter features contribute to letter recognition. For instance, letter "e" was often reported as "c" for Times New Roman font (45%), but not for Courier (1%) and Century Gothic (2%). Letter "w" was frequently reported as "v" for Courier font (42%) but rarely for Times New Roman (2%) and Century Gothic (1%). Letter "a" was often reported as "o" for Century Gothic font (45%) but hardly for Times New Roman (< 0.5%) and Courier (2%). Our findings suggested that the font effect emerges early in text processing. These results also provided insights on how to design or select font for better reading performance.

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56.430 Visual hemifields are a bottleneck for awareness Evan A Reierson[1,2](evan.reierson@gmail.com), Timothy D Sweeny[1]; [1]University of Denver Department of Psychology, [2]University of Denver School of Engineering and Computer Science

Visual processing is constrained by bottlenecks of space and attention. Interestingly, both of these bottlenecks can occur at a large scale—the visual hemifield. For example, object-selective neurons have large receptive fields, often encompassing the entire left- or right-visual field, and attention within each hemifield is supported by independent resources. Notable accounts of object representation (e.g., OSM) propose that iterative processing is engaged to overcome these bottlenecks, continuing until ambiguity about an object's identity and location is resolved. According to this framework, visual awareness of an object should also depend on the completion of this process, and should be gated by processing constraints within the left- and right-visual hemifields. Here, we tested and confirmed this hypothesis. We presented quartets of objects scattered among a variety of peripheral locations. Quartets appeared for 20-msec, with spatial arrangements either within a hemifield or spread across the left- and right-hemifields. Objects included gabors, inverted mooney-faces, and upright mooney-faces, each with a leftward- or rightward-tilt. We used OSM to mask (and cue) one of the peripheral locations, which may or may not have contained an object. On each trial, observers indicated (1) whether an object was present at the masked location, and (2) whether it was tilted to the left or right. Not surprisingly, orientation discrimination was worse when objects were presented within a hemifield compared to across hemifields. More important, within-hemifield arrangements profoundly disrupted detection of an object's presence. These effects occurred for each object type, presumably reflecting the operation of a processing bottleneck that applies to multiple levels of stimulus complexity and/or stages of visual analysis. Our findings cannot be accounted for by differences in crowding or visual acuity. Rather, we have demonstrated a more general phenomenon in which the hemifield-based architecture of visual processing gates access to visual awareness.

56.431 **The Ebbinghaus illusion changes numerosity perception** Saki Takao[1](sakitakao@ruri.waseda.jp), Katsumi Watanabe[1]; [1]Waseda University

A circle surrounded by smaller (larger) circles appears larger (smaller) (Ebbinghaus illusion: Tichener, 1901; Ebbinghaus, 1902). Whether other perceptual qualities are modulated inside the space surrounded by the circles (inducers) has not been fully examined. In the present study, we investigated whether the Ebbinghaus illusion would modulate numerosity perception. In the experiment, participants fixated on the fixation-cross that was continuously presented at the center of the display. In each trial, some dots were presented inside the fixed circle areas at the left and right side of the fixation cross for 200 ms. For each side, the number of dots were selected randomly from 2, 4, 6, 8, 10, or 12. Two inducers surrounded the two areas where the dots were presented. Each inducer was consisted of 4 circles, which were either smaller, the same size as, or larger than the dot area, and presented 200 ms before, during, and 200 ms after the dot presentation (i.e., for 600 ms). Twelve participants were asked to report which dot area contained the larger number of dots. In the experimental trial, one small inducer and one large inducer were presented with their positions randomized. In the control trial, two inducers with the same size as the dot area were presented. Participants performed 720 experimental trials and 360 control trials in a randomized order. The results showed that the number of dots tended to be perceived larger with the small inducer than the large inducer. Evidently, the present study demonstrated that not only size perception but also numerosity perception were modulated by the size of the inducers in the Ebbinghaus illusion.

56.432 **Measuring face-name integration with fast periodic visual stimulation** Angelique Volfart[1,3,4](angelique.volfart@gmail.com), Louis Maillard[3,4], Bruno Rossion[1,2]; [1]Institute of Neuroscience, University of Louvain, [2]Psychological Sciences Research Institute, University of Louvain, [3]Health-Biology-Signal Department, Nancy's Research Center in Automatic, University of Lorraine, [4]Neurology Department, University Hospital Center of Nancy

Associating specific names to faces of familiar identity is crucial for social interactions. This is a difficult process, which can be severely disrupted in neurodegenerative disorders such as Alzheimer's disease or temporal epilepsy. An outstanding issue is whether face and name representations are kept separated in the human brain and associated through re-entrant interactions, or if they are integrated into common representation at higher stages. Here we addressed this issue with fast periodic stimulation in EEG. Healthy subjects (n=12) were exposed to randomly alternating face photographs and written names of a famous identity (base stimuli) at a fast rate (3.999 Hz, about 4 images per second) while recording their brain activity with high density (128 channels) scalp EEG. A change in identity (either presented as a face or a name) occurred every seven stimuli (i.e., 0.5713 Hz; "oddball" stimuli). Following a few minutes of recordings, there were significant electrophysiological responses at the frequency of a face identity change (i.e., 0.5713 and harmonics), suggesting integrated representations of faces and names. Experiment 2 (n=20) replicated these findings and added two control conditions: A face only condition in which the specific identity names presented at the base rate were replaced by other famous names, and a name only condition which followed the same principle for names. There were much weaker amplitudes at the periodic change of identity in control conditions. Most importantly, the sum of the two control conditions' activation was weaker than the effect found in the main condition, in particular over the left medial occipital region and extending to the posterior part of the left occipito-temporal region. Overall, these observations provide evidence for integrated face/name representations in the human brain, with a left occipito-temporal locus.

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56.433 **Shaping perception of individual objects through summary statistical perception** Allison Yamanashi [1](ayleib@gmail.com), Kristin Donnelly[1], David Whitney[1]; [1]Psychology, UC Berkeley, [2]Haas Business School, UC Berkeley

Humans frequently encounter brief marketing displays while scrolling across computer screens, riding on the subway, watching television, or even walking past store windows. These first-glance visual assessments of consumer products are critical moments in early-stage shopping, and prior research from our lab indicates that observers are sensitive to the average value of consumer product groups. In principle, this information could be used to guide behavior, but this remains an unanswered question. Does ensemble information about the value of product groups influence subsequent judgements about individual objects within the groups? To investigate this question, participants viewed individual products with the retailer's price listed underneath. The participants were asked to choose whether the price was a "good price" or a "bad price". In one condition, this 2AFC task was preceded by a 1-second group display (containing the single product among a crowd of other products) and an ensemble price evaluation task that required observers to report the average price of the crowd. In another condition, participants merely viewed the single product before performing the 2AFC price evaluation. Importantly, the evaluated consumer products were identical in both conditions. Replicating our prior results, we show that participants were highly sensitive to the ensemble price of the group. More importantly, the ensemble assessment of the group strongly influenced participants' evaluations of single product value. Participants judged the single items to be a "good price" at a significantly higher rate when the product was preceded by the ensemble task compared to the single-product viewing task. This finding was robust across a range of single product prices and average group prices. These findings indicate that rapid summary statistical impressions can have a crucial impact consumer evaluations of individual product value. More generally, the results reveal one way in which ensemble perception influences subsequent visual processes.

56.434 **Tracking two pleasures** Aenne A Brielmann[1](aenne.brielmann@nyu.edu), Denis G Pelli[1,2]; [1]New York University, Department of Psychology, [2]New York University, Center for Neural Science

Can observers keep track of each pleasure, while enjoying several? In everyday life, images are rarely isolated. Yet, experiments on aesthetic pleasure usually present only one image at a time. Here we ask whether people can reliably report the pleasure of an image even if another image is presented simultaneously and both need to be attended. Participants (N = 13) viewed 36 OASIS images that uniformly span the entire range of pleasure (from very unpleasant to very pleasant) and beauty (from none to very intense). On each trial, the observer simultaneously saw two side-by-side images for 200 ms. A cue (randomly left or right) indicated which image the observer should report the pleasure of (target) while ignoring the other (distractor). In half the blocks, the cue came before the images, and in the other half, it came after. Pre-cueing allows the observer to selectively attend to just the target, while post-cueing demands attention to both images. At the end of the experiment, we obtain baseline pleasure ratings by showing only one image at a time. We model the pre- and post-cued pleasure report as a weighted average of baseline target and distractor pleasure. The data are best explained by a target weight of 1. We obtained accurate selective reports with both pre- and post-cueing, showing that people can encode and report the pleasure of each image while attending to both.

56.435 **Detection of people in natural images can be done with as few as 9x13 samples** Douglas A Addleman[1](addle005@umn.edu), Sha Li[1], Alexander Bratch[1], Daniel Kersten[1]; [1]University of Minnesota Department of Psychology

Detecting other humans is a basic visual function that occurs under a wide range of variability in appearances, in particular those resulting from distance, normal defocus, or impaired acuity. Our goals were to measure resolution limits of human body detection and to investigate whether detection is primarily determined by the effective number of spatial samples. Participants (N=30) were shown natural, color images of human bodies or background scenes and asked to identify whether each image contained a body in a yes-no paradigm. We selected 176 body images and 176 background scene stimuli. Body images were approximately matched for body size, and background images were matched with body images based on scene categories. There were three degradation conditions in which the amount of spatial information was progressively reduced: 1) Size reduced – images were downsampled from 140x205 pixels to between 21x30 and 2x3 pixels, producing 10 images with retinal sizes ranging from 40x57 to 4x6 minutes of arc when viewed from 50 centimeters; 2) Block-averaged – the size-reduced images were upsampled to 13x19 degrees; 3)

Tuesday PM

Low-pass filtered – the block-averaged images were spatially filtered to suppress frequencies above half the Nyquist rate. Images were displayed for up to five seconds per trial, with participants instructed to emphasize accuracy rather than speed. For each participant, an equal number of body and background images were shown at each resolution, and each image was displayed three times; once using each image degradation type. We found that the effective number of samples required to achieve a sensitivity of d'=1 was 12x18, 12x18 and 9x13 spatial samples for conditions 1, 2, and 3, respectively. While spatial filtering (condition 3) improved performance, solely increasing retinal size of the image (condition 2) had no effect on sensitivity.

Attention: Space

Tuesday, May 22, 2:45 - 6:45 pm

Poster Session, Pavilion

56.436 **What does it mean to visually estimate: Re-understanding internal noise as internal confidence for time, space and number** Justin Halberda[1](halberda@jhu.edu); [1]Psychological and Brain Sciences, Johns Hopkins University

Vision science includes a notion of the limited precision of our representations, e.g., internal noise. Here, I present a re-understanding of the contents of visual analog magnitude representations (e.g., approximate duration, distance, density, number). As my main example, I consider the Approximate Number System (ANS), which supports numerical representations that are widely described as fuzzy, noisy, and limited in their representational precision. I contend that these characterizations are largely based on misunderstandings of psychophysical theory. Specifically, I propose that what has been called "noise" and "fuzziness" in these representations (e.g., approximately 7) is actually an important epistemic signal of confidence in my estimate of the value (e.g., think 7, with confidence intervals). As such, I suggest that our analog magnitude representations have precise content that is subject to epistemic limitations. Throughout, I focus on visual magnitude representations (i.e., analog magnitudes) including demos engaging representations of approximate duration (e.g., what does a 1.5 second flash feel like?), approximate distance (e.g., how far does it look to be between me and the wall?), and approximate number (e.g., around how many dots are on the screen?). I describe a standard model for these representations, discuss a confusion we may fall prey to when theorizing about them, present demonstrations of failings of such notions, and present a positive proposal for replacing these notions with the notion of epistemic limitation. The major result of this re-analysis is the proposal that we all share a commitment that there is one true value for any experienced visual magnitude in the world – even if our analog magnitude systems are incredibly limited in their ability to discern what value this is. Visual analog magnitudes do not represent "fuzzy" or "noisy" estimates – rather they represent precise estimates that are subject to epistemic limitations.

56.437 **Temporal order dynamically modulates the interaction between ground suppression and top-down inhibition.** Paige E Scalf[1](paige.scalf@durham.ac.uk), Adam S Richardson[1]; [1]Department of Psychology, Durham University

Our previous work shows that automatic, perceptual processes and top-down attention interact in a specific and multiplicative manner to alter attentional function (Wager et al., 2015). We found that figure-ground segregation, which requires active neural suppression of the ground region, specifically enhances top-down inhibition of task-irrelevant information. It does not affect top-down facilitation. In the current work, we show that the interaction between ground suppression and top-down inhibition is dynamically modulated by the order in which the two processes are initiated. We measured attentional facilitation and inhibition through performance on a flanker task (Eriksen & Eriksen, 1974). Flanker displays were preceded by a silhouette of an unfamiliar shape. The degree of neural suppression required to segment the image was manipulated by altering the familiarity of the groundside outline (Cacciamani et al., 2015; Peterson et al., 2012). Flanker display elements were positioned such that task-relevant stimuli fell within the figural region of the display and task-irrelevant elements fell into the ground region of the display. Critically, flanker display elements could fall in three locations on the display; on fixation, above fixation or below fixation. If flanker elements fells above or below fixation, participants had to shift attention after the onset of the silhouette. Under these conditions, ground suppression preceded attentional inhibition. As in our previous work, interference from inconsistent flanker items was lower when they fell on familiar (high suppression) ground outlines rather than novel (low suppression) ground outlines. If the flanker elements fells at fixation, however, top-down attention was in place prior to ground suppression. Under these conditions, interference from inconsistent flanker items was higher when they fell on familiar rather than novel ground outlines. We discuss the how the temporal relationship between perceptual and attentional processes might change their function.

56.438 **Looking for something big: attentional capture by illusory object size in natural scenes** Surya Gayet[1](surya.gayet@gmail.com), Marius Peelen[1]; [1]Donders Institute for Brain, Cognition and Behaviour

When searching for a relevant item in our visual environment (say, an apple) we create a memory template (e.g., a small circular red object), which causes our visual system to favor template-matching visual input (e.g., apples) at the expense of template-mismatching visual input (e.g., leaves of the apple tree). While this principle seems straight-forward in a lab-setting, it poses a problem in naturalistic viewing: Two objects that produce the same size on the retina, can be of a different size in the real world if one is nearby and the other is far away. We questioned whether visual objects that match the perceived size of a memory template are favored over mismatching visual objects, even when the competing objects encompass the same size on the retina. On each trial, participants were retro-cued to memorize the size of one out of two objects for subsequent recall. During the retention interval, participants swiftly reported the tilt of a target grating. Critically, the target was preceded by a scene comprising two identical objects (of a size in between that of the cued and non-cued objects) that differed in perceptual size due to their placement in the scene (near or far). Finally, participants adjusted the size of a test object to reproduce the size of the memorized object. Gratings appearing on the location of a 'far' object elicited faster response times when a larger object was memorized, whereas gratings appearing on the location of a 'near' object elicited faster response times when a smaller object was memorized. Firstly, these findings show for the first time that memory templates favor concurrent visual processing of size-matching objects (expanding previous findings with color or shape templates). Secondly, our data reveal that memory templates impact the processing of visual input at a perceptual rather than veridical level.

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56.439 **Internal Attention Elicits Surround Suppression in Visuospatial Working Memory** Wanghaoming Fang[1](fangwan1@msu.edu), Susan Ravizza[1], Taosheng Liu[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

Goal. Attention can be oriented externally to environmental stimuli or internally to memory representations. Both types of attention can modulate visuospatial working memory performance and engage overlapping cortical areas. While the spatial profile of external attention has been characterized, the profile of internal attention remains unclear. Using a pre-cue and retro-cue paradigm, we investigated the spatial profile of both external and internal attention. Methods. We presented memory arrays consisting of six disks with random colors, evenly distributed on an imaginary circle. After the array, a probe disk appeared at the same location of one of disks in the array. Participants adjusted the probe's color until it matched the color of the memorized disk in that location. External and internal attention was manipulated using a predictive pre-cue or retro-cue, respectively. The cue correctly indicated the probe location in half of the trials; for the remaining trials, the cue could indicate an item at a location that was either 1, 2, or 3 items away from the probe. Memory performance was measured as the absolute angular difference on a color wheel between the recalled and presented color. The baseline (no-cue) condition was included to assess attentional modulation. Results. External attention reduced memory error on valid trials, but in a non-monotonic pattern as a function of cue-target distance; that is, the largest error was observed at the intermediate distance, but a smaller error was observed at the farthest cue-target distance. This implies a surround suppression mechanism of external attention. Importantly, we found a similar non-monotonic pattern for internal attention, in which performance was the worst at the 2-item distance but rebounded for the farthest distance. Conclusion. Our results demonstrate surround suppression for both internal and external attention. Attention may select internal representations in a similar way as selecting stimuli in the environment.

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56.440 **Visual short-term memory load does not enhance attentional selection** Hyuksu Lee[1](hyuksu.lee@yonsei.ac.kr), Do-Joon Yi[2]; [1]Department of Psychology, Yonsei University, [2]Department of Psychology, Yonsei University

Lavie's load theory posits that high cognitive load impairs attentional selection since the distinction between targets and distractors cannot to be actively maintained (Lavie et al., 2004). Thus, it has been assumed that taxing any types of working memory (WM) might increase distractor processing in a concurrent selection task. Two of recent studies disproved this assumption: holding multiple items in visual short-term memory (VSTM) enhances visual selection (Konstantinou, Beal, King, & Lavie, 2014; Roper & Vecera, 2014). The authors suggested that the encoding and maintenance in VSTM might deplete perceptual resources for filtering distractors. Notwithstanding their plausible arguments, however, here we report a series of four experiments, in which we consistently failed to reproduce such effects. Participants performed a canonical flanker task while maintaining colors of squares in VSTM. We contrasted the low load versus high load conditions (1 vs. 4) in an intermixed design or in a blocked design (Experiment 1 and 2, respectively), or the no load versus high load conditions (0 vs. 3) in a blocked design (Experiment 3). In all three experiments, flanker interference did not decrease with VSTM load. This failure of replication cannot be ascribed to a floor effect; flanker interference did decrease with perceptual demand (Experiment 4). We further tested any potential effects of the spatial overlap between the flanker and the memory items. VSTM load exacerbated, but not alleviate, flanker interference only when the two locations were not overlapped (Experiment 5). Finally, we submitted all four VSTM experiments to the equaivalence test (Lakens, 2017), and found that the effects of VSTM load on flanker interference were statistically equivalent to zero. Overall, our results call for new models, within which the dynamic relationships between VSTM and selective attention are fully described and tested.

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56.441 **Learning-induced changes in attentional priority map are task-specific** Sha Li[1](lixx3632@umn.edu), Roger R Remington[1,2,3], Yuhong V Jiang[1,2]; [1]Department of Psychology, University of Minnesota, [2]Center for Cognitive Sciences, University of Minnesota, [3]School of Psychology, University of Queensland

Extensive behavioral and neuroscientific evidence supports the concept of an "attentional priority map," in which locations receiving higher weights are preferentially attended or prioritized. The weighting of locations is sensitive to prior search history and reward, suggesting that this map can adapt to one's previous visual experience. Here we investigated the specificity of priority learning across tasks. Using stimuli that mimic X-ray images, we employed a detection task that required participants to find a heavily camouflaged target among 1/f2 noise. In a separate discrimination task, the noise opacity was reduced, but the target appeared among visually similar distractors. The two tasks were associated with similar response time and accuracy, and both entailed a sequence of eye movements. To modify the attentional priority map, the target, when present, was more often located in one quadrant than the others during a training phase. This manipulation of location probability successfully induced a change in the priority map: participants more quickly found the target in the high-probability quadrant than the low-probability quadrants. To investigate the persistence and transfer of the learned spatial priority, we also measured response during a testing phase, in which the target appeared in all quadrants equally often. When the same task was used in both training and testing, the learned priority persisted in the testing phase for over 100 trials. But when the task changed across training and testing, the learned priority immediately ceased in the testing phase. Eye tracking showed fewer, but longer, fixations in the detection task than in the discrimination task. These results suggest that changes in the attentional priority map are task-specific, even when the tasks are performed in the same general space. These findings have implications for attention training in applied settings, such as cancer detection.

56.442 **Dissociating two forms of inhibition of return using temporal order judgments** Ralph S. Redden[1](rredden@dal.ca), Austin J. Hurst[1], Raymond M. Klein[1]; [1]Dalhousie University

Inhibition of return (IOR) is an inhibitory aftereffect of visuospatial orienting, typically observed in the spatial cueing paradigm by way of slower responses to cued rather than uncued targets. Early work on IOR using temporal order judgments (TOJ; Posner, Rafal, Choate & Vaughan, 1985; Maylor, 1985; Klein, Schmidt & Muller, 1998) showed no effect on arrival time judgments, suggesting IOR is acting at a post-perceptual information processing stage, although at precisely what stage - attentional or motoric - has been quite contested (Taylor & Klein, 2000; Abrams & Dobkin, 1994; Ivanoff & Klein, 2006; Ivanoff, Klein & Lupianez, 2002). Recent work, however, suggests that there are two forms of IOR (Chica, Taylor, Lupianez & Klein, 2010; Hilchey, Klein & Satel, 2014; Klein & Redden, in press; Redden, Hilchey & Klein, 2016); one operating nearer the input end of the information processing continuum affecting the quality of inputs and the other nearer the output end affecting responding, whereby the type of effect that is manifest is contingent upon the activation state of the reflexive oculomotor system at the time the effect is generated. We tested this theory in a TOJ task, where subjects were required to either make a prosaccade (output form) or antisaccade (input form) after the onset a spatially uninformative peripheral cue, and subsequently execute a TOJ or speeded colour identification response. Both groups showed inhibited RT for colour probes presented at the cued location. We saw dissociable effects on colour identification depending on whether input or output IOR was generated. Furthermore, we found inhibited perceptual processing in the TOJ task when the input form was generated, but no effect on TOJs in the group that elicited the output form. These findings provide converging evidence that there are two forms of IOR: an input effect operating on a saliency map, and an output effect operating on a priority map.

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56.443 **Cueing effects for simple detection are best accounted for by a decision model of selective attention** Miranda Petty[1](mlpetty@uw.edu), John Palmer[1], Cathleen M Moore[2], Geoffrey M Boynton[1]; [1]University of Washington, [2]University of Iowa

When given a spatial cue indicating where a visual target is likely to occur, observers are better at detecting the target when it appears at the likely, cued location than when it appears at an unlikely, uncued location. Two competing hypotheses have been used to account for this partially-valid cueing effect: selective perception with limited-capacity perception, and selective decision with unlimited-capacity perception. The goal of the current experiment was to distinguish these hypotheses. In particular, we focused on simple detection, which has previously been shown to be processed with unlimited-capacity. Participants completed a partially-valid cueing task with simultaneous and sequential displays. The target was a brief, low-contrast Gabor patch presented at one of two locations 10 degrees into the periphery. For each trial, there was a visual cue indicating where the target was likely to appear. The probability of the target appearing at the cued location was .8 (high-probability), and at the uncued location it was .2 (low-probability). In the simultaneous condition, the cued and uncued locations were presented simultaneously within one stimulus interval, whereas in the sequential condition these locations were presented sequentially in two stimulus intervals separated by a full second. For our selective perception hypothesis, a cueing effect is predicted for only simultaneous displays, while for our selective decision hypothesis, a cueing effect is predicted for both simultaneous and sequential displays. Results show a cueing effect for both the simultaneous and sequential conditions, which is inconsistent with selective perception with limited-capacity perception. Instead, this result is consistent with selective decision with unlimited-capacity perception.

56.444 **Rethinking capacity limits in visual processing: Peripheral vision, attention, and decision limits** Ruth Rosenholtz[1](rruth@mit.edu); [1]Brain & Cognitive Sciences/CSAIL, MIT

 See page 3 for Abstract Numbering System

Human vision is full of puzzles. Observers can grasp the essence of a scene in an instant, yet when probed for details they are at a loss. People have trouble finding their keys, yet they may be quite visible once found. How does one explain this combination of marvelous successes with quirky failures? Researchers have attempted to provide a unifying explanation in terms of mechanisms for dealing with limited capacity. In particular, a popular proposal posits limited access to higher-level processing, that a mechanism known as selective attention serially gates access to that processing, and that the gate operates early in visual processing. This account, however, has been problematic. More recently, my lab has argued that many of these puzzling phenomena confound selective attention with an alternative mechanism for dealing with limited capacity: an efficient ("compressed") encoding in peripheral vision. In this scheme, visual processing has limited bandwidth rather than limited access to higher-level processing. Recent results from my lab and others necessitate revisiting whether selective attention mechanisms operate early in visual processing, whether attention serves as a gate to further processing, and whether there exists a dichotomy between tasks that do and do not require attention. I will argue that there is little evidence for these popular concepts. Nonetheless, evidence does exist for limited capacity beyond merely limited bandwidth. Dual task performance is often worse than single task, and observers perform better when they know the task. Additional capacity limits may exist late in processing, taking the form of general limits on what tasks one can perform at a given moment. I will discuss how we might test this hypothesis.

Acknowledgement: NSF CRCNS

56.445 **Effect of background texture on target detection: masking or differential processing for near and far pictorial depth?** Jiali Song[3](songj16@mcmaster.ca), Hong-Jin Sun[3], Patrick J. Bennett[3], Allison B. Sekuler[1,2,3]; [1]Rotman Research Institute, Baycrest Health Sciences, [2]Department of Psychology, University of Toronto, [3]Department of Psychology, Neuroscience & Behaviour, McMaster University

It is well established that the 2D spatial extent of selective attention is limited, as described by the useful field of view (UFOV), the 2D spatial extent of the visual field from which information can be extracted without eye or head movements. However, less is known about how selective attention varies in 3D. We (Song et al., VSS 2017) previously investigated the horizontal extent of visual attention while simulating depth through pictorial and optical flow cues in a driving scenario. In our modified UFOV task, participants showed better detectability for brief peripheral targets at a near depth compared to a far depth. Although we ensured that the retinal size of the targets was identical across both depths, the retinal characteristics of the textured, checker backgrounds on which targets appeared differed across conditions. Specifically, backgrounds in the far condition extended over a smaller area and consisted of smaller checkerboards than backgrounds in the near condition. Thus, the depth effect we found previously may have been due to increased masking effects of the background at greater simulated depths, rather than differences in perceived depth per se. The current study examined this hypothesis by measuring the effect of check size and background extent on the detectability of brief peripheral targets presented at a single depth. Results from 13 observers suggest that check size and background extent have very small effects on the detectability of peripheral targets in our conditions. Hence, it is unlikely that the effect of depth reported by Song et al. can be accounted for by differential masking by the target background in the near and far conditions, supporting the idea that attention covers a greater extent for near than for far targets. We are continuing this line of investigation by examining the effect of the ground texture on target detection.

Acknowledgement: NSERC

56.446 **Inhibition of return at different eccentricities in visual field under three-dimensional (3D) world** Aijun Wang[1](wangaijun41123@126.com), Xiaole Liu[1], Ming Zhang[1]; [1] Department of Psychology, Research Center for Psychological and Behavioral Sciences, Soochow University

It has been well documented that inhibition of return (IOR) is much stronger in the periphery relative to the perifoveal visual field in two-dimensional (2D) space. However, we live in a three-dimensional (3D) space and operate objects that lie at different depth planes,it remains poorly understood whether IOR is homogeneously distributed throughout the visual field. In the present study, by constructing a virtual 3D environment and presenting the target either closer to or farther from the participants in an adapted version of the Posner spatial-cuing paradigm, we aimed to investigate the IOR at the different eccentricities in 3D space. The experimental design was a two (depth of target: near vs. far) by two (cue validity: cued vs. uncued) by three (stimulus eccentricity: foveal vs. perifoveal vs. periphery) within-participants design. The different target distances were simulated by adjusting the binocular disparity. The binocular disparity between the near and far depth planes was ±52.40 min of arc, relative to the fusion plane at which the central location in mid plane was presented (zero disparity). Participants reported that they could clearly perceive both the near and far depth planes when fixating the central location in the mid plane. Results showed that when secondary cued location was located at the central field, regardless of the target appeared at the near or far depth plane, the IOR effect was larger in the periphery filed than in the foveal and perifoveal fileds. When secondary cued location was located at the periphery field, the IOR in near and far depth planes appeared dissociated, specifically, when target appeared at the far depth plane, the IOR effect was reduced in periphery filed. The results indicated that the IOR is heterogeneity in different eccentricities in the visual field under the 3D space.

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56.447 **Dissociating attentional shifting and attentional engagement: behavioral and ERP evidence** Alon Zivony[1](alonzivony@gmail.com), Ayala Allon[1], Roy Luria[1,2], Dominique Lamy[1,2]; [1]The School of Psychological Sciences, Tel-Aviv University, Israel, [2]Sagol School of Nueroscience, Tel-Aviv University, Israel

What happens when we shift attention towards a specific location? Most models of spatial attention assume that attention operates like a spotlight and that stimuli appearing in the focus of attention are mandatorily processed. In contrast to this claim, we provide evidence that shifting attention to a location can be dissociated from extracting an object's identity at that location (attentional engagement). Participants searched for two red targets embedded in one of two visual streams of gray distractors. Prior to the second target, a red distractor (cue) appeared either in the same or in the other stream relative to the target. It appeared either during the period of the attentional blink triggered by the first target or outside the blink. Finally, it enclosed a stimulus that elicited a response that was either compatible or incompatible with the response elicited by the target. We show that attentional capture by the cue remained intact during the blink, whereas the response compatibility effect (indicative of attentional engagement) was reduced during the AB. This dissociation allowed us to clarify the mechanisms underlying a widely used electrophysiological index of spatial attention, the N2pc. We replicated our first study, while also measuring ERPs. We show that the N2pc component was suppressed during the blink, whereas the lateralized P1 component, which is known to reflect spatial allocation of attention, was not. The contribution of these findings is twofold. First, they suggest that attentional engagement does not necessarily follow attentional shifting, which opens the door for a new model of spatial attention. Second, they show that the N2pc does not index attentional shifting but attentional engagement.

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56.448 **Late enhancement of visual attention after multi-method brain stimulation** Grace CA Edwards[1,2](gcaedwards1@gmail.com), Federica Contò[1,3], Loryn Bucci[4], Lorella Battelli[1,2,5]; [1]Center for Neuroscience and Cognitive Systems@UniTn, Istituto Italiano di Tecnologia, Rovereto, Italy, [2]Department of Psychology, Harvard University, Cambridge, MA 02138, USA, [3]Center for Mind/Brain Sciences – CIMeC, University of Trento, 38122 Trento, Italy, [4]Boston College, Boston, MA, 02467, [5]Berenson-Allen Center for Noninvasive Brain Stimulation and Department of Neurology, Beth Israel Deaconess Medical Center, Harvard Medical School, Boston, Massachusetts, USA, 02215

Low-frequency rTMS (lf-rTMS) to the intra-parietal sulcus (IPS) in the healthy hemisphere of patients with parietal lesion leads to improved visual attention up to 30 minutes post-rTMS. This behavioral improvement may be due to upregulation of functional communication in the

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attention network, compensating for the inhibited IPS. However, to aid clinical intervention, enduring effects that outlast lf-rTMS are crucial. We hypothesize stimulation effects may persist through multi-method stimulation. We paired 20-min transcranial random noise stimulation (tRNS) with lf-rTMS in healthy subjects (n=5) to examine if priming the cortex with tRNS can prolong subsequent lf-rTMS effects in a bilateral multiple object tracking task. Participants were asked to track two moving discs amidst two moving distractor-discs in each visual field, either side of a fixation point. Prior to stimulation, disc speed was thresholded to the speed at which subject performance was 75% correct. The four within-subjects, neuro-navigated stimulation sessions consisted of: 1) tRNS over bilateral IPS with subsequent lf-rTMS over left IPS, and 2) over right IPS, 3) SHAM-tRNS over bilateral IPS with subsequent lf-rTMS over left IPS, and 4) over right IPS. We normalized tRNS conditions relative to SHAM-tRNS, ensuring effects specific to the tRNS and lf-rTMS combination. Results showed that tRNS extended the effect of rTMS. Specifically, in the visual field ipsilateral to lf-rTMS, there was an initial boost in tracking performance but only after lf-rTMS to the right IPS. This is potentially an effect of priming the cortex with bilateral tRNS, resulting in left IPS excitation. In the contralateral visual field to rTMS, there was an initial decrement in tracking ability, followed by a late improvement at 82 minutes. The late enhancement on contralateral attention may reflect functional compensation of inhibited IPS. Our results demonstrate a prolonged modulation in behavioral response to visual-field specific attention after multi-method stimulation.

56.449 **The minimal size of the attentional window is larger when measured via the pupillary light response** Shira Tkacz-Domb[1](shirtzi@yahoo.com), Yaffa Yeshurun[1]; [1]University of Haifa, Israel

The goal of this study was to measure the minimal size of the attentional window (i.e., its size when attention is narrowly focused) using attentional modulation of the pupillary light response (PLR) – pupillary constriction when covertly attending a brighter area relative to attending a darker area. This allowed us to avoid confounds and biases involved in relying on observers' response (e.g., RT). Specifically, we presented a continuously rotating T to the right and left of fixation at an eccentricity of 7°. Four task-irrelevant disks surrounded each T with varying inter-stimuli distances (Experiment 1: 1°, 4°, 7° or 11°; Experiment 2: 1°, 2°, 3° or 4°). The disks were bright on one side and dark on the other. Prior to the onset of the Ts and disks, a central cue instructed observers which T to attend. The task was to indicate the number of times the attended T assumed an upright orientation. Overall luminance levels were identical across trials. In both experiments, pupil size was modulated by the disks' luminance only when they were positioned 1° away from the T. That is, with this inter-stimuli distance pupil size was significantly smaller when the disks surrounding the attended T were bright than when they were dark. With larger distances pupil size was not affected by the luminance of the disks at the attended side. Hence, it seems that at a distance of 1° from the target the task-irrelevant disks were nevertheless attended, suggesting that the radius of the attentional window is at least 1°, but less than 2°. These findings reveal that the minimal size of the attentional window is twice as large as that established when relying on RT. Currently, we use PLR to examine whether the size of the attentional window scales with eccentricity.

56.450 **Facilitation and inhibition in selective attention: Two sides of the same coin?** Dirk van Moorselaar[1](dirkvanmoorselaar@gmail.com), Heleen A Slagter[1]; [1]University of Amsterdam

A long-standing question in attention research has been if and how attention can suppress distracting information. Previous studies addressing this question often used paradigms in which the task-relevant location was known beforehand, so that observers could simply pay more attention to the relevant location to prevent distraction. This renders it unclear whether enhancement and suppression always co-occur, as two sides of the same coin, or whether they subserve independent mechanisms. We conducted two behavioural and one EEG experiment to examine whether observers can selectively suppress irrelevant locations and the underlying neural mechanisms. Search displays with repeating target or distractor locations across trials allowed observers to learn which location to selectively attend or suppress. Both learned attention and suppression resulted in more efficient search as indexed by faster response times. Crucially, suppression was observed without target-location foreknowledge, unaffected by the number of possible target locations, and could not be explained by priming. To determine how distractor-location foreknowledge facilitated performance, we applied a spatial encoding model to EEG data to reconstruct activity in neural populations tuned to the relevant or irrelevant location. Target-location foreknowledge increased neural tuning to the relevant location prior to stimulus presentation, indicative of enhanced attention. This sensitivity increased after target presentation. By contrast, distractor repetition only changed neural tuning to the distractor location immediately preceding visual stimulation, and subsequently reduced distractor processing, as reflected in a flattening of the tuning curve and the disappearance of the Pd ERP component. These findings suggest independent facilitatory and inhibitory attentional mechanisms.

56.451 **The effects of attentional scope on voxel receptive fields and population codes for space** Vy A Vo[1,2](vyaivo@ucsd.edu), John T Serences[1,2,3]; [1]Neurosciences Graduate Program, [2]Dept. of Psychology, [3]Kavli Institute for Brain & Mind

Prior studies in both humans and macaques have investigated how spatial attention alters the response properties of spatial encoding units -- e.g. single neurons in macaques, or single voxels in humans – across different cortical areas. These studies have all shown that spatial receptive fields (RFs) change their center, shape, and gain with spatial attention (for review, see Anton-Erxleben & Carrasco 2013; in humans, see Klein et al. 2014; Sprague & Serences 2013; de Haas et al. 2014; Kay et al. 2015; Sheremata & Silver 2015; Vo et al. 2017). In these studies, subjects typically attend to a single stimulus of a fixed size and scope (but see Niebergall et al. 2011). It remains unknown how patterns of RF changes across the visual field might support spatial attention divided across many stimuli. We had human participants perform a task in which they focused their attention on 1 of 3 locations or divided their attention across all 3 locations. As a control, they also performed a contrast change discrimination task at fixation. We threshholded task difficulty to equate performance across conditions. They then performed the task in an fMRI scanner as we measured BOLD signals across the whole brain. We compare how (1) voxel RFs (vRFs) changed across attention condition, and (2) how population codes for space changed across condition by using an inverted encoding model. Preliminary data suggest that altering the spatial scope of attention causes widespread changes in the preferred center, size, and gain of vRFs. These modulations across the whole population of vRFs jointly influence the quality of information encoded about spatial location in each condition.

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56.452 **Is Spatial Attention-Modulated Surround Suppression Observed Across Development?** Audrey Wong-Kee-You[1](audwky@yorku.ca), Scott A. Adler[1, 2]; [1]Department of Psychology, York University, [2]Centre for Vision Research

Studies have demonstrated that there is a suppressive surround for any given spatial location of attentional focus in which information is inhibited (e.g., Hopf et al., 2006). Though several studies have provided psychophysical (e.g., Cutzu & Tsotsos, 2003) and neural evidence of this effect in adults (e.g., Boehler et al., 2009), whether this phenomenon is also observed earlier in development is unknown. To examine this, adults, adolescents and school-age children were tested on a two-alternative forced choice visual task, in which their accuracy in discriminating between two target letters (Ls and Ts) was measured. A spatial cue guided attention to the upcoming location of one of the target letters. Following the cue, a visual array consisting of 6 randomly oriented Ls and 6 randomly oriented Ts, arranged inon a circle grid centered on a central fixation point was displayed. The distance between the two target letters varied among six values of inter-target separation distances. Results have indicated that, as would be predicted for adults, accuracy increased linearly as the inter-target separation distance increased, suggesting that visual processing is suppressed in the immediate vicinity of an attended location. Adolescents showed a similar pattern but greater accuracy increases were observed for the larger inter-target separation distances. Further, adolescents' accuracy did not increase as gradually and linearly as with adults. Finally, school-aged children did not exhibit accuracy differences across inter-target separation distances. Thus, there were clear developmental differences in visual discrimination accuracy and the

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impact of surround suppression. These findings, therefore, seem to show a clear developmental trend in the efficacy of top-down processing and related attentional mechanisms, and their impact on perceptual processing and discrimination.

Acknowledgement: Hallward Fund of the Toronto Foundation

Attention: Eye movements

Tuesday, May 22, 2:45 - 6:45 pm

Poster Session, Pavilion

56.453 **Impact of Birth Experience on Adults' Selective Attention and Eye Movements** Scott A Adler[1,2](adler@yorku.ca), Audrey M.B. Wong-Kee-You[1,2], Kyle J Comishen[1], Solomon Sabovich[1]; [1]Department of Psychology, York University, [2]Centre for Vision Research, York University

Selective attention is a vital gating mechanism for determining which available information is further processed and the nature of the subsequent cognitive or behavioral action. Studies, using a spatial cueing paradigm in which a peripheral spatial cue facilitates detection and behavioral responses to subsequent targets (Posner, 1980), have shown that adults produce saccadic eye movements with shorter latencies when they are cued indicating facilitation of attentional selection (Adler, Bala, & Krauzlis, 2002). A recent study demonstrated that 3-month-old infants' saccadic latencies in a similar spatial cueing task are sensitive to prior birth experience (Adler & Wong-Kee-You, 2015). Results indicated that caesarean section delivered infants exhibited slower latencies to localize the cued target than those born vaginally. This is likely due to the lowering of serotonin levels and differentiation of the somatosensory cortex that typically occurs during the birth process (Toda et al., 2013), not occurring during caesarean section. The present study addressed whether the attentional effect of birth experience observed in infants was transient or more permanent. Results indicated that, in the same spatial cueing task as used with infants in which targets were either preceded by a peripheral spatial cue or not, adults also exhibited differences in saccadic latencies as a function of birth experience. In contrast to infants, however, the effect direction was reversed, with adults having faster latencies when delivered by caesarean section than when delivered vaginally. One explanation is that the caesarean section impacts bottom-up attention, requiring over-compensation of the top-down system. As a consequence, adults exhibit more top-down anticipation of the cued targets that speeds their responses, a likelihood supported by caesarean section delivered adults exhibiting more incorrect anticipatory saccades than vaginally delivered adults. In sum, the findings show that birth experience has significant implications for selective attentional allocation that persists even into adulthood.

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56.454 **The degree of gaze-induced shifts in overt attention explains inter-subject variability in long-term memory performance** Touchai Thawai[1,2](touchai.thawai@gmail.com), Sakol Teeravarunyou[1,2], Geoffrey F Woodman[3], Sirawaj Itthipuripat[1,3]; [1]Learning Institute, King Mongkut's University of Technology Thonburi, Bangkok, 10140, Thailand, [2]School of Architecture and Design, King Mongkut's University of Technology Thonburi, Bangkok, 10140, Thailand, [3]Department of Psychology, Vanderbilt University, Nashville, TN, 37203, United States

Gaze is an important cue thought to facilitate effective social interaction and communication. Previous studies have shown that gaze could induce an attentional shift toward a location that match gaze direction and this attentional shift could in turn enhance sensory information processing in simple perceptual tasks. However, less is known about how gaze cues may influence selective attention and long-term memory in more complex real-world tasks. To examine this issue, we monitored eye movements via an infrared eye-tracking camera in 95 male and female adults, while they were reading and listening to sentences containing autographical information. On some trials, the sentence was presented by itself. On other trials, there was also an animated facial stimulus, which either gazed toward the sentence (congruent), gazed directly to the viewer (neutral), or gazed away from the sentence (incongruent). We found that the congruent gaze cue effectively induced overt shifts of attention to the sentence as the probability that the eyes landed on the sentence increased compared to the incongruent gaze cue. Moreover, the degree of gaze-induced attentional modulations in the eye movement data positively correlated with the degree of attentional modulations in long-term memory performance. Taken together, these results suggest that gaze could induce overt attentional shifts toward relevant information in a complex behavioral task that requires learning and memory. Moreover, the attentional enhancement of memory performance varies across individuals depending on the degree at which social cues influenced attentional and oculomotor systems.

Acknowledgement: Learning Institute, King Mongkut's University of Technology Thonburi, Thailand

56.455 **Attentional Repulsion Effect: the influence of response mode and microsaccades** Denise Baumeler[1](denise.baumeler@unige.ch), Sabine Born[2]; [1]University of Geneva, [2]University of Geneva

The Attentional Repulsion Effect (ARE) is a bias attributed to a covert shift of attention towards a peripheral cue, which in turn repulses the perceived position of a target stimulus presented outside the focus of attention (Suzuki & Cavanagh, 1997). The bias is typically examined through a two-alternative forced choice task (2AFC), measuring the capacity of the cue to repel the target across the vertical meridian. To investigate the robustness of the ARE, we compared the classic 2AFC task to a condition in which participants were asked to indicate the absolute perceived location of the target by a computer mouse click. While the two response conditions revealed an ARE of similar magnitude, the computer mouse responses additionally exposed an increased repulsion the further away the target was presented from the cue. This increase, however, declined at a maximum cue-target distance of 4 degrees of visual angle. Covert shifts of visual attention have previously been related to microsacades, miniature fixational eye movements. Therefore, we also tested whether the directional distribution of microsaccades might contribute to the ARE. Microsaccadic responses to cue onset displayed typical dynamics with an initial inhibition followed by a rebound interval (as described in Engbert & Kliegl, 2003). More interestingly, the direction of microsaccades in the cue-target interval was biased towards the cue. These microsaccades support the idea that the ARE may reflect a small shift in the spatial frame of reference: A covert attentional shift towards the cue leads to a presumably unrecognized change in the spatial reference point around fixation (and sometimes in gaze, i.e., a microsaccade). Although target positions are assessed by the visual system in relation to this biased spatial reference point, subsequent responses are given in comparison to the initial point of fixation. These distortions then induce a repulsed spatial representation of the target.

56.456 **An oculomotor contribution to the attentional blink** Dorothy L Ayres[1](d.ayres885@gmail.com), Stephen Heinen[2], Scott Watamaniuk[1,2]; [1]Dept. of Psychology, Wright State University, [2]The Smith-Kettlewell Eye Research Institute

The attentional blink (AB) is a well-studied phenomenon in which a second target in a rapid serial visual presentation (RSVP) stream is more difficult to identify when it appears about 300 ms after the first target. Models of the AB attribute the effect to attentional bottlenecks at various levels of target processing. An independent line of oculomotor research shows that microsaccades quiesce in anticipation of a target and then resurge ~200-300 ms after target appearance. Furthermore, microsaccades can reduce target visibility because of excessive retinal-image motion or saccadic suppression. The coincidental timing of the microsaccade resurgence and the typical AB suggested to us that these events might be related. To produce AB, observers performed a task in which they detected a letter in one of two RSVP streams located 3 deg to the left and right of the fixation point. In each RSVP stream, a new character appeared every 100 ms On one-half of the trials, a second letter target appeared after a variable number (0-5) of intervening numerals. Eye movements were recorded at 1000 Hz with an EyeLink 1000 eye tracker while observers performed the task. Microsaccades (saccades with amplitudes < 1.0 deg) were detected offline using the Eyelink analysis software and visual inspection. We found that the timing of microsaccade occurrence was correlated with the drop in performance characteristic of the AB function. Moreover, when the RSVP streams were embedded in a larger stimulus (6 peripheral dots at the same eccentricity as the RSVP streams creating a circular object) both the AB and microsaccade rates were reduced. The results suggest that the occurrence of microsaccades may contribute to the AB, providing an alternative explanation for this phenomenon.

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56.457 **Attentional fingerprints: Individual differences in gaze behaviour** Ben de Haas[1,2](benjamindehaas@gmail.com), Alexios I Iakovidis[2], D. Samuel Schwarzkopf[2,3], Karl R Gegenfurtner[1]; [1]Department of Psychology, Justus Liebig Universität Giessen, Germany, [2]Experimental Psychology, University College London, UK, [3]School of Optometry & Vision Science, University of Auckland, New Zealand

Recent findings in twin children suggest a heritable component for fixation behaviour towards social1 and complex2 scenes, revealing systematic variability in gaze behaviour. However, the nature of these differences and their persistence into adulthood are largely unclear. Here, we present results of an experiment tracking the gaze of 52 adults freely viewing 700 complex scenes for 3s each. We harnessed semantic annotations for >5,500 objects3 to probe the magnitude and consistency of individual differences in semantic salience3,4. Observers showed large and surprisingly consistent differences in the average number of objects they fixated and in their average dwell time per object (split half reliability for both r=.99). We further investigated the proportion of fixations towards objects from different semantic categories. This revealed considerable and highly consistent (r=.73-.98) individual differences in semantic salience for eight out of twelve tested categories: faces, emotional expressions, food, text, watchable objects, implied motion, smell, touch. For faces, this extended to an analysis limiting the data to the first fixation landing on each image (r=.79). Furthermore, the spatial distribution of faces drawing first fixations consistently varied between observers (r=.94 for average eccentricity). Our findings suggest that gaze behaviour is marked by attentional 'fingerprints': highly individual tendencies for visual exploration and for fixations along dimensions of semantic saliency. At least for faces this seems to extend to 'salience' in a stricter sense, suggesting the existence of a face priority map with individually different extent. This opens a new window for the study of attentional selection and suggests a potential link between individual differences in perception, personality and behaviour.

1. Constantino et al. Nature 547, 340–344 (2017). 2. Kennedy et al. Curr. Biol. 27, 3554–3560.e3 (2017). 3. Xu et al. J. Vis. 14, (2014). 4. Henderson & Hayes Nat. Hum. Behav. 1, 743–747 (2017).

56.458 **The Wandering Eye: A novel method for the objective measurement of mind wandering in real time** Geoffrey W Harrison[1](8gh3@queensu.ca), Eden Shaul[1], Philip Aucoin[2], Jordan Poppenk[1], Daryl E Wilson[1]; [1]Department of Psychology, Queen's University, [2]Department of Innovation in Medical Education, University of Ottawa

Whether writing a grant application, or driving a car, research suggests we spend nearly half our waking life thinking about something other than what we are currently doing (Killingsworth & Gilbert, 2010). Instead, we are mind-wandering (MW), which is the process of attention drifting from task focus to the processing of task-unrelated information. Importantly, our current understanding of MW is limited by two methodological pitfalls. First, behavioural tasks used to measure MW provide very coarse temporal resolution (several seconds to minutes). Second, these tasks rely on subjective reports to determine the occurrence of MW. The current project presents a novel, objective measure of MW that reliably predicts the onset of MW with a temporal resolution of 100ms. In this task, participants track an object with their eyes and report self-caught MW with a keypress. To assess MW objectively we correlated eye and target position over time (using a 100ms moving window). We observed that large deviations in this correlation reliably preceded self-reported MW. Taking trials where such deviations occurred (83%) and treating the deviations as indicators of MW onset, histograms of MW duration were created for 9 different MW phenotypes. These phenotypes represent three classes of self-reported distraction (external, internal task-related, internal task-unrelated) and three levels of self-reported task focus. When mostly paying attention to the task, distraction type did not affect MW duration; however, when only some attention was paid to the task, MW duration increased as distraction became more internal and less task-related. Interestingly, despite mean MW durations of 1500-3000ms, the duration distributions displayed a strong positive skew with some episodes lasting over 15 seconds. These results strongly challenge the use of arbitrary MW duration windows currently employed in MW task analysis, and further justify the development of an objective online measure of MW.

Acknowledgement: NSERC

56.459 **Dissociating spatial orienting biases from selection demands with eye movements** Matthew D Hilchey[1](matthew.hilchey@utoronto.ca), Mark Mills[1], Jay Pratt[1]; [1]University of Toronto

There is ambiguity surrounding whether attentional orienting is biased in favor of or against locations that were previously attended in two-forced choice stimulus discrimination tasks. In the simplest case, a target appears abruptly in a distractor-less environment and its location randomly repeats from moment-to-moment. Here, there are response repetition tendencies whenever the target location repeats and roughly equal tendencies to switch from the prior response whenever the prior target location switches. These opposing effects equivocate whether there are orienting biases. In more complex cases, a unique target color is embedded in an array of homogenous distractors colors; once found, its shape is discriminated with a manual response. These "priming of pop-out" studies show faster responding overall whenever the target location repeats, suggesting that attention may be biased in favor of the prior target location. However, the magnitude of these positive position priming effects is determined by whether the response repeats, such that there is often little to no effect when the response switches. Thus, here too it is unclear to what extent position priming reflects an attentional orienting bias. In this study, we resolve this ambiguity. In our first set of experiments, four diamonds form an imaginary square centered on a fixation stimulus. The target diamond is a color singleton, and once found, its shape is discriminated. The findings reinforce prior observations showing that positive position priming is response-mediated. Our hypothesis is that position priming is tied to the effector making the discrimination judgment. If so, then we should observe an orienting bias in the eyes that is not contaminated by the processes involved in making manual discrimination judgements. Therefore, in our second set of experiments, we require eye movements to each target prior to the manual discrimination response and we find an orienting bias.

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56.460 **Attention operates in saccade coordinates, not perceptual coordinates** Sirui Liu[1](sirui.liu.gr@dartmouth.edu), Kevin Hartstein[1], Peter Ulric Tse[1], Patrick Cavanagh[1,2]; [1]Department of Psychological and Brain Sciences, Dartmouth College, Hanover, NH, USA, [2]Department of Psychology, Glendon College, Toronto, ON, Canada

When we see a target, we might expect that both our eye movements and attention would be directed to the target's perceived location. Numerous studies have shown a tight link between attention and saccade system (Moore & Zirnsak, 2017) so ideally, attention, perception and saccades should all be in alignment. There is, however, one stimulus that gives dramatically different outcomes for saccades and perception: a moving Gabor with its internal texture drifting orthogonally to its path. The perceived path of this double-drift stimulus deviates from its physical path by a remarkable 45° or more (Tse & Hsieh, 2006; Shapiro et al., 2010, Kwon et al., 2015; Lisi & Cavanagh, 2015). Surprisingly, saccades go to the physical location of the double-drifting Gabor, not to its perceived location (Lisi & Cavanagh, 2015). Since saccades and perception disagree strongly here, we can test whether attention operates in saccade or perceptual coordinates. We used transformational apparent motion (Hikosaka et al., 1993) to test the location of attention drawn to the endpoint of the Gabor's path. We flashed a line arranged to fall between the physical and illusory endpoints of the path. If attention was at the perceived location of the Gabor, subjects should see an illusory motion away from the perceived endpoint; however, the motion was reported overwhelmingly to proceed away from the physical location of the Gabor's offset. Our results suggest that attention, at least under these conditions, operates in the coordinates of the saccade system and not in the coordinates of perception.

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56.461 **Oculomotor behavior during non-visual tasks: the role of visual saliency** Dekel Abeles[1](d_abeles@msn.com), Roy Amit[2], Shlomit Yuval-Greenberg[1,2]; [1]School of Psychological Sciences, Tel Aviv University, [2]Sagol School of Neuroscience, Tel Aviv University

During visual exploration or free-view, gaze positioning is largely determined by the tendency to maximize visual saliency: more salient locations are more likely to be fixated. However, when visual input is completely irrelevant for performance, such as with non-visual tasks, this saliency maximization strategy may be less advantageous and potentially even disruptive for task-performance. Here, we examined whether visual saliency remains a strong driving force in determining gaze positions even in non-visual tasks. In three experiments, gaze position was monitored as participants performed visual or non-visual tasks while they were presented with complex or simple images. Exploratory behavior was evident even when the task was non-visual, and the visual input was entirely irrelevant. This included a strong tendency to fixate salient locations, central fixation bias and a gradual reduction in saliency for later fixations. These exploratory behaviors were spatially similar to those of an explicit visual exploration task but they were, nevertheless, attenuated. Temporal differences were also found; in the non-visual task there were longer fixations and later first fixations than in the visual task, reflecting slower visual sampling in this task. We conclude that during non-visual tasks, the visual system samples visual information at a lower rate but based on similar selection mechanisms as those that govern visually motivated tasks.

Acknowledgement: Israel Science Foundation (ISF)

56.462 **Visual Salience Model of Active Viewing in 360° Real-World Scenes** Caroline E Robertson[1,2](carolinerobertson@fas.harvard.edu), Jefferey S Mentch[1], Nancy G Kanwisher[1]; [1]McGovern Institute for Brain Research, MIT, Cambridge, MA, [2]Harvard Society of Fellows, Harvard, Cambridge, MA

Vision is an active process. We typically explore our 360° visual environment through self-directed movements – saccades and head turns. How does active vision impact the balance of semantic-level (meaning-based) and bottom-up (feature-level) signals during active, natural scene viewing? Here, we tested how well a traditional multi-level salience model of eye-tracking behavior captured viewing patterns during active viewing of 360° real-world scenes. 12 adults participated in a visual salience experiment in which 360° viewing behavior was measured using a head-mounted display (HMD) (Oculus Rift; resolution: 960x1080; field-of-view: ~100°; 75Hz) and an in-headset eye-tracker (120Hz; 5.7ms latency; 0.5° accuracy). We developed a stimulus bank of 300 complex, real-world 360° panoramic scenes and applied each image to a Virtual Reality environment built in Unity3D. During each trial of our Study Phase (duration: 15s), participants actively explored one novel 360° panoramic scene, using head turns to change their viewpoint as they would in a real-world environment. Participants were instructed that a "memory test" would follow the Study Phase, and were given ample breaks throughout the duration of the experiment. Previous studies of gaze behavior – in which participants view static, single-frame images on a fixed display – dispute whether gaze behavior is most guided by semantic-level salience or feature-level salience (e.g. Henderson et al., 2017; Anderson et al., 2015; Itti and Koch, 2001). Our results are consistent with the hypothesis that the balance of the contributions of each of these levels is mediated by active-viewing: gaze-behavior during active viewing conditions is relatively more aligned with meaning-based salience models than observed in previous studies. This study provides a quantitative measurement of visual behavior during active, real-world scene-viewing. Down the road, this paradigm will enable us to isolate levels of visual representation that drive atypical visual behavior in clinical populations, such as autism.

56.463 **Fixation Patterns to Celebrities and Selfies following Image and Task Modification** Tiffany Arango[1](arango.t@husky.neu.edu), Peter Bex[1]; [1]Psychology Department, College of Science, Northeastern University

Normally-sighted participants (N=6) viewed 150 images of famous faces or selfies under 4 conditions: upright, inverted, Mooney or Canny line drawings. Face images were 17x23 degrees, and normalized by aligning the pupils at a separation of 7 degrees. After viewing each image for 5 seconds, in separate blocks, observers identified either the written name or an image feature (right eye, left eye, left ear, right ear, nose, chin, mouth and forehead, at random across trials) in a 2AFC task. The name or feature of the test face was paired with a name or same feature from a different face. Binocular gaze direction was tracked using a 60Hz eye tracker. Face identification was significantly worse for line drawings than upright faces ($p < .0001$). Gaze direction varied as a function of face feature ($p < 0.001$) with more fixations towards the eyes and nose than any other features (all $p < 0.05$), and more fixations to left than right eye (all $p < 0.05$). Participants made fewer fixations on the eyes of all non-upright faces or selfies compared to upright faces (all $p < 0.05$), but fixation patterns were not significantly different for face naming than feature recognition ($p < 0.87$). In agreement with previous research, gaze direction is not uniformly distributed across faces. However, changes in image type can modify the pattern of eye movements at no expense to identification accuracy. Furthermore, changes in task type failed to modify fixation patterns. These findings are not consistent with a single information-driven goal of eye movements.

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56.464 **Reward-predicting stimuli accelerate contextual cueing and modulate eye movements** Nils Bergmann[1](nils.bergmann@uni-marburg.de), Dennis Koch[1], Anna Schubö[1]; [1]Cognitive Neuroscience of Perception and Action, Department of Psychology, Philipps University Marburg, Germany

Stimuli which signal upcoming reward have extensive influence on visual selective attention and the processing of a visual scene. Reward expectation can draw visual attention in a scene even when this is irrelevant or counterproductive for the observer's actual task. The present experimental investigation examined the influence of reward-predicting stimuli on learning of repeated context regularities when these stimuli were properties of a visual scene. In a contextual cueing task reward-signaling colors were assigned to three different reward magnitudes, with one color present in every search display, which consistently predicted the subsequent reward outcome. We assumed that reward magnitude would affect subsequent learning of context configurations and would favor learning of repeated relative to novel context configurations. Participants performed a contextual cueing task in two sessions on separate days which allowed examining long-term effects. Results revealed an acceleration of contextual cueing, i.e., faster responses to targets presented in repeated compared to novel contextual configurations, an effect that was most pronounced when contexts were associated with high reward relative to medium or low reward magnitudes. In addition to target response times also the analysis of eye movements revealed that the first fixation was closer to the respective target location in repeated contexts associated with high reward. Differences in response times between novel and repeated context configurations were found for both experimental sessions, although the contextual cueing effect was less pronounced in the second session. As the colors signaling reward magnitudes were neither response relevant nor predictive of the target location, we concluded that reward expectation facilitated context learning due to prioritized processing of contexts associated with high reward. This influence manifested also in early modulations of eye movements emphasizing the crucial role of attention guidance for the modulation of emerging context learning.

Acknowledgement: This research was supported by the Deutsche Forschungsgemeinschaft (German Research Foundation SFB/TRR 135, TP B3, and RTG 2271).

56.465 **Coarse and Fine Visual Attention Strategies during a 3D Mental Rotation Task** Stephanie M Saltzmann[1](ssaltz2@lsu.edu), Katherine C Moen[1], Leslie G Butler[2], Jagannathan Ramanujam[3,4], Alex S Cohen[1], Steve G Greening[1], Melissa R Beck[1]; [1]Psychology, Louisiana State University , [2]Chemistry, Louisiana State University , [3]Electrical & Computer Engineering, Louisiana State University , [4]Center for Computer and Technology, Louisiana State University

There is ongoing debate about whether mental rotation is best completed with a whole object versus a part based approach. In a typical mental rotation task, two objects are presented side-by-side and the participant determines if one of the objects is a rotated version of the other. This process likely requires (1) encoding a representation of the first fixated object (whole or part), (2) then attending to the second object, and then (3) rotating the mental representation of the first to determine if it matches

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the second object. Across this process, different scales of attention allocation may be employed (whole versus part). In the current study we examined participants' eye movements as they completed the mental rotation task in order to track the allocation of attention across time. Replicating previous research, as angular disparity increased, accuracy decreased and reaction time increased (Just & Carpenter, 1985; Stieff, 2007). Eye tracking data revealed that participants began each trial with brief fixations separated by longer saccades on one object, suggesting that participants were coarsely encoding the whole object. Then participants switched attention to the second object and used an encoding strategy geared toward encoding a part of the object (longer fixations and shorter saccades). This was followed by shifting attention back to the first object and using a part based attention allocation (longer fixations and shorter saccades) to process this object. Therefore, across switches between objects, there was an increase in fixation duration and a decrease in saccade amplitude, suggesting a switch from a coarse to a fine attention allocation (Over et al., 2007). Finally, males' accuracy was higher than females' and there was a positive correlation between accuracy and saccade amplitude for males, suggesting that using a whole object approach could be more effective in improving performance for males than for females.

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Eye Movements: Attention, salience, search, reading

Tuesday, May 22, 2:45 - 6:45 pm

Poster Session, Pavilion

56.466 **Including temporal information into prediction of gaze direction by webcam data** Katerina Malakhova[1](katerina.malahova@gmail.com), Evgenii Shelepin[1]; [1]Pavlov Institute of Physiology, Laboratory of physiology of vision

Eye tracking is the process of measuring gaze location, which is widely used in behavior research, marketing studies, and assistive technologies. Most eye tracking devices use a light source to illuminate the eye and high-resolution near-infrared cameras to detect the iris and light reflections. The ability to implement eye-tracking using web- and mobile cameras would significantly change the situation. Although some webcam-based solutions (Xu et al., 2015; Cheung & Peng, 2015) have appeared recently, the technology still lacks required accuracy to become widespread. Here we investigate how the processing of temporal information about gaze position can improve the basic performance. Convolutional neural networks (CNNs) show exceptional performance in image processing and can be useful for predicting gaze direction by webcam data. To see if CNN-based solutions could gain from including temporal information about eye movements, we integrate them with Long Short Term Memory networks (LSTMs). As a base CNN model, we use the iTracker CNN (Krafka et al.). We retrained the CNN on our dataset, which preserves temporal information and contains 19 hours of simultaneous recording of a webcam and eye-tracking data of 32 users performing everyday tasks, such as web browsing, video watching, reading, etc. We create multiple LSTM networks, different in size and number of layers and train on 700K of gaze observations (100K are used for testing). Then we compare the performance of the LSTMs to identify the best combination of data preprocessing and the architecture. The results show that the performance can be significantly improved by taking into account the temporal information about gaze position during the prediction process.

56.467 **Flow of the eye: Gaze direction as an objective measure of flow experience** Mohammad Shehata[1,2](shehata@caltech.edu), Salma Elnagar[1,3], Shota Yasunaga[1,4], Shigeki Nakauchi[2], Shinsuke Shimojo[1]; [1]Division of Biology and Biological Engineering, California Institute of Technology, CA, [2]Department of Computer Science and Engineering, Toyohashi University of Technology, Japan, [3]University of Cambridge, UK, [4]Pitzer College, CA

INTRODUCTION: Flow is a mental state in which a person performing an activity, at the appropriate skill-challenge level, experience high focus and control, enjoyment, effortless action, and reduced self-consciousness and sense of time (Csikszentmihalyi et al., 1975, 2014). So far, most studies identify the flow through subjective questionnaires (Jackson et al., 2008, 2010). Only few studies tried to establish an objective measure of flow utilizing physiological measures such as heart, vascular or hormonal changes (Manzano et al., 2010; Peifer et al., 2014; Tozman et al., 2016) or auditory evoked potential measured through electroencephalogram recording (Shehata et al., unpublished). Here, we tested the utilization of eye measures as an objective measure of flow. METHODS and RESULTS: We used a music rhythm game to induce flow in 8 healthy volunteers. In experiment 1, three conditions were used for each music of choice: "Easy", "Normal", or "Overload" based on the number of notes to respond to, thus, creating a low, fit, or high skill-challenge levels, respectively. Blinking rate and gaze direction (towards notes entry) were found to reflect the skill-challenge level (N=8). In experiment 2, "Easy" condition was replaced by "Boredom" condition which matches "Normal" condition in the number of notes but the notes were repetitive and the music was shuffled. Thus, "Boredom" condition manipulated the enjoyment element of flow, confirmed through a subjective questionnaire, without affecting the sensory-motor load. Here, only gaze direction was found to reflect the enjoyment level while blinking rate was related only to the notes number (N=6). CONCLUSION: Gaze direction was found to reflect both the appropriate skill-challenge level and high enjoyment as critical elements of the flow, providing a promising objective flow measure. It is more objective and feasible to measure, with a higher temporal resolution and accuracy, relative to the previously reported objective measures.

56.468 **Characterizing the gain change underlying presaccadic attention** Jasmine Pan[1](jp3580@nyu.edu), Hsin-Hung Li[1], Marisa Carrasco[1,2]; [1]Department of Psychology, New York University, [2]Center for Neural Science, New York University

Goal Visual responses at the saccade landing location are enhanced before the eyes move, a phenomenon known as presaccadic attention. Here, we investigate whether such enhancement is mediated by contrast gain or response gain. Method In a fine orientation discrimination task, the target was a Gabor patch (4 cpd) presented at one of two locations (8° left or right of fixation). The target orientation was tilted either clockwise or counterclockwise from vertical on each trial. The degree of tilt was titrated for each observer. We tested the target at 9 contrast levels (5%-95%). In the saccade condition, a pre-cue instructed observers to saccade to the cued location. Shortly after the pre-cue (12-224 ms), the stimulus was presented (35 ms) at the cued location. In the neutral condition, a pre-cue pointed to both locations instructing observers to maintain fixation. Observers reported the orientation of the target following an auditory response cue (400 ms after target offset). The frequency of the response cue (low or high tone) indicated the target location (left or right). Results We binned the data relative to saccade onset. We fit performance (d') as a function of contrast with a Naka-Rushton function. The three free parameters were dmax, C50 and n, representing asymptotic performance, semi-saturation contrast and exponent, respectively. Compared to the neutral condition, presaccadic attention increased asymptotic performance at high contrasts, indicating a response gain change. This modulation became more pronounced closer to the time of saccade onset. We did not observe a change of semi-saturation contrast between conditions. Conclusion Presaccadic attention enhances the saccade target through response gain. This finding serves as a critical step toward understanding the neural computations underlying presaccadic attention.

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56.469 **Exogenous Orienting of Peri-Saccadic Spatial Attention** Ilana Naveh[1,2](ilanaveh@gmail.com), Yuval Porat[1], Ehud Zohary[1,2]; [1]The Edmond and Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Jerusalem 91904, Israel, [2]Department of Neurobiology, The Alexander Silberman Institute of Life Sciences, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

The premotor theory of attention suggests that spatial attention is deployed at the saccade target, just before saccade onset. In this study, we use a peri-saccadic cue to exogenously direct attention to other locations. A brief stimulus, presented during the saccade, is also perceived closer to the saccade target than it actually is - a phenomenon called "saccadic compression". This unique situation enables studying the coordinate frame in which priming occurs: does the cue enhance performance at the real (screen) position of a stimulus, in its retinal position, or in its perceived position? Our goal was to exogenously orient spatial attention

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during a saccade, using a Posner cue, to a position other than the saccade target. We assessed the advantage conferred by the cue in a post-saccadic discrimination task. To that end, we briefly presented a priming cue (for 12 ms) during a saccade. 120 ms later, a Vernier target randomly appeared at one of six different positions: the screen position of the cue; its misperceived position; the cue position in retinal coordinates; and the three homologous, equidistant, "non-cue" (control) locations. The cue carried no information about the future position of the Vernier target. Nevertheless, significant priming effects ($p < 0.006$) were found in both the real and the perceived location of the cue. Our results suggest that peri-saccadic deployment of spatial attention can be directed to locations other than the saccade target. Interestingly, the cueing effects were most prevalent in the real or perceived cue position. Attention was therefore sustained at the cue's location in the world (or its perceived location) despite the change of retinal position. This is likely to be a consequence of a physiological remapping process - predictive activation of visual neurons when an attended stimulus will fall in their future receptive field after completion of the saccade.

56.470 **Endogenous spatial and feature-based attention outside the saccadic range** Gozde Senturk[1](senturkgozde@hotmail.com), Taosheng Liu[1]; [1]Psychology Department, College of Social Science, Michigan State University

The ability to make saccade is necessary for exogenous spatial attention (Smith & Schenk, 2012), but its necessity for endogenous attention is not well known. We investigated whether endogenous space- and feature-based attention can operate at a location out of the range for saccades. We used an abduction procedure with monocular viewing to manipulate saccadic range. In normal sitting position, both nasal and temporal visual fields were within the saccadic range. During abduction, participants sat in a rotated position (25°) while fixating the screen center, such that the temporal visual field was outside the saccadic range. Importantly, stimuli were presented at identical retinal locations in both normal and rotated positions. In Experiment 1, we manipulated spatial attention by instructing participants to attend to either a central RSVP stream or a moving-dot stimulus (adaptor) in the periphery (31.5° eccentricity). We measured the motion aftereffect (MAE) via a speed nulling procedure. The difference in MAE strength between attending to the adaptor versus the RSVP stream was used to quantify the effect of space-based attention. We found attending to the adaptor yielded a larger MAE than attending to the RSVP stream, for both the normal and rotated sitting positions, equally for both hemifields. In Experiment 2, we manipulated feature-based attention by instructing participants to attend one of two superimposed moving dot fields at the center of the screen. The MAE was then measured in two peripheral locations, similar to Experiment 1. The MEA induced by attending to upward vs. downward motion was used to quantify the effect feature-based attention. We found attention-induced MAE spread equally to both hemifields regardless of sitting position. In conclusion, the ability to make an eye movement to a location is not necessary for either endogenous space- or feature-based attention to operate at that location.

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56.471 **Saliency Map Classification Using Capsule-based CNNs** Michael J Kleiman[1](kleiman@scikey.net), William E Hahn[1], Elan Barenholtz[1]; [1]Florida Atlantic University

Inference of task based on eye movements, known as the inverse Yarbus process, is challenging. Previous approaches have used aggregate measures, such as mean fixation duration or saccade velocity as well as hand-selected areas of interest (AOIs), with classification accuracies above chance but with high loss rates. Here, we used Capsule-based Convolutional Neural Networks (CapsuleNets), a recently introduced modification of convolutional neural networks (CNNs), to identify a participant's task (counting objects vs aesthetic judgement) based only on saliency maps derived from raw eye fixation coordinate data. Traditional CNNs have been widely used for classification of visual data, including types of flowers or species of animals, and are highly accurate in many situations. CNNs function analogously to the human visual system, with highly sparse representations such as edges or patches leading to progressively more specified layers such as faces or noses, and ultimately followed by subject classification based on the activation of each layer. However, CNNs suffer from an inability to process spatial information, which restricts their utility for ambiguous or irregular images, or images where spatial information is especially important -- both of which are the case when discriminating between saliency maps of varying tasks. By introducing capsules, the neural network is able to utilize spatial locations of features such as a cluster of fixation points around an expected search target versus a more spread out cluster for a non-target. Results show that CapsuleNets improve accuracy rates and minimize loss for saliency map classification by up to 35% compared to traditional CNNs. This method of saliency map analysis provides a method for classification of eye movement data that is highly generalizable to different tasks and stimuli types.

56.472 **Human Saliency Prediction using Conditional Generative Adversarial Neural Networks** William Hahn[1](williamedwardhahn@gmail.com), Mark Lenson[1], Elan Barenholtz[1,2]; [1]Center for Complex Systems and Brain Sciences, [2]Department of Psychology

Understanding image saliency is useful for modeling human perception as well as providing computer vision systems richer representations of the scene. Most traditional methods for saliency-map generation rely on predefined features that typically detect image regions with high degrees of change within a combination of dimensions. In the last few years deep learning models, such as convolutional transpose techniques, have shown great promise in their ability to generate accurate heatmaps. However, these techniques require a hand-designed loss function to determine the accuracy of the model, which may be sensitive to the particular choice of the experimenter. Here, we present a novel, 'model-free' method for the generation of saliency maps from RGB images based on conditional generative adversarial networks (cGANS). GANS use a pair of neural networks, a 'generator' network that produces an output with the goal of fooling the 'discriminator' network into misclassifying the output as a member of a training class. In traditional GANS, the generator takes random noise as inputs, with the goal of generating variable outputs. In cGANS, both structured inputs (such as text or images) and noise are presented to both the generator and discriminator to produce a more specific output. cGANS have recently been successfully deployed using images as the conditional inputs in order to generate a target transformation such as grayscale images to color. We trained two different models using two datasets: CAT2000 and FIGRIM. Both of these datasets provide the original stimulus image together with the heatmap that represents the fixation duration of the eye tracked human viewers. To test performance of these models we measured the peak signal-to-noise ratio, structural similarity, and histogram intersection of similarity as well as the Pearson's linear coefficient to find the linear correlation between two different saliency maps. Our models showed competitive performance with previously established benchmarks.

56.473 **Predicting fixation densities over time from early visual processing** Heiko H Schütt[1,2](heiko.schuett@uni-tuebingen.de), Lars O M Rothkegel[2], Hans A Trukenbrod[2], Ralf Engbert[2], Felix A Wichmann[1]; [1]Neural Information Processing Group, University of Tübingen, Germany, [2]Department of Experimental and Biological Psychology, University of Potsdam, Germany

Bottom-up saliency is often cited as a factor driving the choice of fixation locations of human observers, based on the (partial) success of saliency models to predict fixation densities in free viewing. However, these observations are only weak evidence for a causal role of bottom-up saliency in natural viewing behaviour. To test bottom-up saliency more directly, we analyse the performance of a number of saliency models---including our own saliency model based on our recently published model of early visual processing (Schütt & Wichmann, 2017, JoV)---as well as the theoretical limits for predictions over time. On free viewing data our model performs better than classical bottom-up saliency models, but worse than the current deep learning based saliency models incorporating higher-level information like knowledge about objects. However, on search data all saliency models perform worse than the optimal image independent prediction. We observe that the fixation density in free viewing is not stationary over time, but changes over the course of a trial. It starts with a pronounced central fixation bias on the first chosen fixation, which is nonetheless influenced by image content. Starting with the 2nd to 3rd fixation, the fixation density is already well predicted by later densities, but more concentrated. From there the fixation distribution broadens until it reaches a stationary distribution around the 10th fixation. Taken together these observations argue against bottom-up saliency as a mechanistic

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explanation for eye movement control after the initial orienting reaction in the first one to two saccades, although we confirm the predictive value of early visual representations for fixation locations. The fixation distribution is, first, not well described by any stationary density, second, is predicted better when including object information and, third, is badly predicted by any saliency model in a search task.

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56.474 **Assessing the dynamic visual processing of informative local features with eye movements** Anna Montagnini[1](Anna.Montagnini@univ-amu.fr), Anna Paola Benini[1,2], Maria M. Del Viva[2]; [1]Institut de Neurosciences de la Timone, Aix-Marseille Universitè & CNRS , France, [2]Dipartimento NEUROFARBA, Università degli Studi di Firenze, Italy

Visually salient features embedded in synthetic structured images typically attract a rapid foveating saccade even under very challenging visual conditions. However, a general definition of saliency, as well as its role for natural active vision are still matter of debate. Here we chose a specific set of local features, predicted by a constrained maximum-entropy model to be optimal information carriers (DelViva et al. 2013), as candidate salient features. These local patterns are spatial arrangements of 3x3 black and white pixels (about 9 arcmin of size). At each trial we randomly selected 10 patterns for the target stimulus (s of them being classified as salient, with s=1,4,6 or 10) and 10 non-salient patterns for the distractor. In a choice saccadic experiment we randomly presented target and distractor for 26ms on the right and left side of the screen respectively, at 5º eccentricity from the central fixation and at different angles (0º, ±45º; ±75º) with respect to the horizontal meridian. We recorded human participants' eye movements while they were asked to perform a saccade towards the most salient pattern. We estimated the oculometric target-selection curves based on the landing position of the first and second saccade with respect to the target and evaluated saccadic choice performance with respect to saccadic latencies. In addition we analyzed saccadic curvature as a possible landmark for an automatic capture of salient patterns. Results point to a dynamic evolution of oculomotor selection with a fast but imperfect attraction of salient patterns and a further refinement resulting in a more accurate second saccade for the highest values of signal to noise ratio. When analyzing the first saccade in more detail, choice accuracy improved with saccadic latency only for the highest SNR values, whereas saccadic curvature was slightly biased toward the non-targeted visual stimulus, regardless of its saliency.

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56.475 **Effects of visual search target-distractor congruence on stimulus-response mapping in macaques: Performance strategies** Kaleb A Lowe[1](kaleb.a.lowe@vanderbilt.edu), Thomas R Reppert[1], Jeffrey D Schall[1]; [1]Vanderbilt Vision Research Center, Center for Integrative & Cognitive Neuroscience, Department of Psychology, Vanderbilt University, Nashville, TN

The general goal of this work is to develop a visual search task that allows decomposition of functionally distinct processing stages through the analytic logic of separate modifiability. Monkeys are trained to search for an elongated color singleton among distractors. The orientation of the singleton specifies the stimulus-response mapping rule; pro-saccade for a vertical singleton and anti-saccade for a horizontal singleton. Distractors could be square or elongated. Elongated distractors create a new task demand; singleton and distractor orientation can be congruent (specifying saccades to same endpoint) or incongruent (saccades to opposite endpoints). Performance of this task requires multiple, sequential operations: localizing of the color singleton, encoding the shape of the singleton, encoding the instructed stimulus-response mapping, selecting the endpoint of the saccade, and preparing and initiating the saccade. Are errors in this task due to incorrect identification of the singleton, incorrect stimulus-response mapping, or both? Performance was impaired in anti-saccade (44% correct) versus pro-saccade (86%) trials. Errors revealed 3 patterns: (1) errant anti-saccades avoided the singleton (3% to singleton, 94% to distractors); (2) errant anti-saccades were concentrated on stimuli closer to the correct endpoint than to the singleton (set size 6, 64% to distractors flanking the correct endpoint, 28% to distractors flanking the singleton); and (3) errant saccades were primarily made to vertical stimuli (64 ± 11% to vertical, 13 ± 3% to square, 14 ± 5% to horizontal). These observations indicate that errors are not due to incorrect singleton localization or identification, but instead are due to either (a) incorrect stimulus-response mapping or (b) the use of an unintended strategy. These results will guide future studies of the neural correlates of the locus of failures of the sequential operations accomplishing this task.

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56.476 **Effects of visual search target-distractor congruence on stimulus-response mapping in macaques: Saccade timing and vigor** Thomas Reppert[1](thomas.reppert@vanderbilt.edu), Kaleb A Lowe[1], Jeffrey D Schall[1]; [1]Vanderbilt Vision Research Center, Center for Integrative & Cognitive Neuroscience, Department of Psychology, Vanderbilt University, Nashville, TN

The general goal of this work is to develop a visual search task for macaque monkeys that allows decomposition of functionally distinct processing stages through the analytic logic of separate modifiability. Monkeys are trained to search for an elongated color singleton among distractors. The orientation of the singleton specifies the stimulus-response mapping rule; pro-saccade for a vertical singleton and anti-saccade for a horizontal singleton. Distractors could be square or elongated. Elongated distractors create a new task demand; singleton and distractor orientation can be congruent (specifying saccades to same endpoint) or incongruent (saccades to opposite endpoints). Performance of this task requires multiple, sequential operations: localizing of the color singleton, encoding the shape of the singleton, encoding the instructed stimulus-response mapping, selecting the endpoint of the saccade, and preparing and initiating the saccade. We assessed the effects of stimulus-response mapping and target-distractor congruence on response time (RT) and peak saccade velocity (PV). We observed that RT was prolonged in anti-saccade (mean = 336 ms) relative to pro-saccade (238 ms) trials. We also observed that RT was prolonged on incongruent (318 ms) relative to congruent (278 ms) trials. Saccade velocity was also influenced by task demands. PV was lower in anti-saccade (mean = 394 deg/sec) relative to pro-saccade trials (411 deg/sec), and PV was lower on incongruent (398 deg/sec) vs. congruent (403 deg/sec) trials. These results extend prior studies of behavioral effects of sensory and cognitive interference in monkeys and humans. The magnitude of singleton-distractor congruency offers a new measure of the efficiency of attentional filtering in monkeys. These results will guide future studies of the neural correlates of the sequential operations necessary to accomplish this task.

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56.477 **Send Help! SOS Effects Arise in Proofreading, as Revealed by Eye Movements** Eliza Barach[1](ebarach@albany.edu), Heather Sheridan[1]; [1]University at Albany, SUNY

In visual search tasks with multiple targets, the discovery of one target can hinder the detection of another target (i.e., "subsequent search misses", SSM; Cain, Adamo, & Mitroff, 2013, which are also known as "satisfaction of search" misses, SOS; Tuddenham, 1962). Although subsequent search misses have been extensively investigated in radiological search tasks, the effect also generalizes to non-medical tasks (Fleck, Samei, & Mitroff, 2010). In the present study, using eye tracking, we examined whether proofreading would be susceptible to SSM errors. Participants' eye movements were monitored while they proofread paragraphs containing 0, 1 or 2 typos. Using this task, we explored how the detection of a high-salience typo (i.e., an easy to detect typo, such as mjaor instead of major) affects subsequent search, as well as the processing and detection of a second low-salience typo (i.e., a difficult to detect typo, such as mitsake instead of mistake). The results revealed an SSM effect where accuracy for the low-salience typo was worse when a high-salience typo was detected relative to when that low-salience typo was presented alone in a paragraph. Further, the detection of the high-salience target lead to faster reaction times, faster time to first fixation on the low-salience target and faster trial termination after fixating the low-salience target. Also, after discovering the high-salience target, participants exhibited shorter fixation times on the low-salience target, as well as a lower probability of re-fixating the

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low-salience target. This pattern of results supports the satisfaction of search (SOS) explanation of SSM errors, by suggesting that the participants conducted a less thorough search following the detection of a high-salience typo. Finally, the results reveal that SSM errors can extend to proofreading, which is a complex task that involves searching for typos in a highly structured visual array.

56.478 **Suppressing the Magnocellular Pathway in Skilled Readers: An Eye Movement Study** Stephen J Agauas[1](stephen.agauas@gmail.com), Laura E Thomas[1]; [1]Center for Visual and Cognitive Neuroscience, North Dakota State University

Deficits in magnocellular stream activity have been implicated as a factor in individuals with developmental dyslexia. While many investigations direct efforts at understanding magnocellular processing as it applies to dyslexia, its role in skilled adult readers remains relatively unexplored. Using diffuse red light, which is known to suppress activity in the magnocellular channel (e.g., Breitmeyer & Breier, 1994), we examined how this pathway affects lexical processing as reflected in eye movements. Our investigation explored the role of the magnocellular stream in extrafoveal vision during skilled adult reading by employing a gaze-contingent moving window paradigm (McConkie & Rayner, 1975, 1976). We predicted that readers would have difficulty efficiently using extrafoveal information when the magnocellular stream is suppressed. As a result, when text is presented on a red background, readers should exhibit slower reading rates, an increased number of fixations, and increases in time per fixation. Additionally, magnocellular stream suppression might result in a reduction in the number of characters useful to readers in extrafoveal vision. We employed a within-subjects factorial design in which readers viewed sentences on either grey or red backgrounds while the number of characters available to the right of a reader's fixation (4, 8, 12, 16, or open) varied across sentences. Not surprisingly, window size reliably affected eye movement measures up to 12 letters to the right of fixation. In addition, readers required additional time per fixation when viewing sentences on a red background compared to when readers viewed sentences on a grey background. Readers may have required additional time at each fixation due to a reduction in the quality of extrafoveal visual information during the previous fixation. These findings warrant further investigation in order to determine the specific lexical information processed by the magnocellular stream.

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56.479 **Eye movements reveal the visual component of music expertise: Evidence from a music-related visual search task** Kinnera S Maturi[1](kmaturi@albany.edu), Heather Sheridan[1]; [1]Department of Psychology, University at Albany, SUNY

An important component of expertise is the ability to rapidly recognize domain-related perceptual patterns. To explore this ability in the domain of music reading, we monitored the eye movements of expert musicians (with a minimum of 10 years of music reading experience) and novices (who could not read music) while they completed a music-related visual search task. Specifically, the participants rapidly located target bars of piano sheet music within larger music scores that varied in visual complexity. Throughout each trial, the target bar was always displayed above the music score to allow the participants to make visual comparisons between the score and the target bar during their search. Both experts and novices were able to complete this visual search task with a high level of accuracy, which allowed us to explore visual search strategies across a wide span of expertise. Also, since the task did not require music performance, we were able to control for potentially confounding variables, including tempo differences across music scores of varying complexities. Relative to visually complex music scores, the visually simple music scores elicited faster reaction times, longer saccades, and fewer fixations. As well, the task elicited strong expert/novice differences; relative to novices, the experts showed faster reaction times, faster fixation times, and fewer fixations. Surprisingly, the experts displayed shorter saccade amplitudes than the novices during this task, which might have occurred because the novices were making long comparison saccades to compare the bar that they were currently processing with the target bar at the top of the screen. Overall, the results are consistent with the predictions of chunking and template theories of human expertise, and the results build on previous findings from other domains (e.g., medicine, chess, face perception, etc.) by demonstrating the remarkable ability of experts to rapidly recognize complex visual patterns.

56.480 **Visual expertise in a music reading flicker paradigm: Evidence from eye movements** Abigail L Kleinsmith[1](akleinsmith@albany.edu), Heather Sheridan[1]; [1]University at Albany, State University of New York

A hallmark of visual expertise is the ability to efficiently encode domain-related visual patterns. We explored this perceptual component of expertise in the domain of music reading by monitoring the eye movements of expert musicians (with a minimum of 10 years of music reading experience) and novices (who could not read music) while they completed a music-related flicker paradigm task. Specifically, participants searched for a single note in a music score that was rapidly appearing and disappearing (with a blank screen presented in between each screen change). This change detection paradigm allowed us to explore interactions between expertise and visual complexity using stimuli that varied dramatically in complexity. As well, this paradigm allowed us to study a wide span of expertise differences (since both experts and novices could complete this task with high accuracy rates), while also controlling for potentially confounding effects of variables known to vary across music scores (e.g., tempo differences between simple and complex pieces during musical performances). Using this paradigm, we demonstrated strong effects of both expertise and complexity. Relative to visually complex music scores, visually simple scores elicited shorter fixation durations, shorter dwell durations, larger saccade amplitudes, faster times to the first fixation on the changing note (i.e., "time to first fixation"), and faster reaction times. Further, relative to novices, experts displayed shorter dwell durations, larger saccade amplitudes, faster time to first fixation, and faster reaction times. Interestingly, visual complexity interacted with expertise, such that novices displayed larger complexity effects than experts. This pattern of results is consistent with the predictions of chunking and template theories of human visual expertise. The increase in expertise effects for complex music scores may reflect the expert musicians' ability to use their memory for domain-related visual configurations to compensate for increases in complexity.

Attention: Neural mechanisms

Wednesday, May 23, 8:15 - 10:00 am, Talk Room 1

Moderator: Yaoda Xu

61.11, 8:15 am **Visual selective attention in mice** Richard Krauzlis[1](richard.krauzlis@nih.gov), Lupeng Wang[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, NIH

Mice have emerged as a useful animal model for studying aspects of the visual system, but have not yet been shown to exhibit visual selective attention. In fact, the discrepancies between the visual and cognitive abilities of primates and mice raise the possibility that mice might not have selective visual attention, at least not in the forms well-known in primates. Here we tested for selective visual attention in mice, using three behavioral paradigms adapted from primate studies of attention. We trained head-fixed mice running on a wheel to detect a threshold-level change in a visual stimulus with distractors, and provided visual spatial cues that indicated the likely location of the relevant visual change. Because our mice reported their detection by licking a central spout, and the visual change occurred in either the right or left visual field, we were able to measure lateralized effects on perceptual choice without confounds from biases in motor responses. We found spatially specific changes in perceptual sensitivity, criterion and reaction times. In a Posner-style cueing task, a spatial cue indicated the probable location of the relevant visual event, and we found that valid cues increased response accuracy and shortened reaction times. In a cue versus no-cue task, an informative spatial cue was provided on half the trials, and we found that the spatial cue again increased response accuracy and shortened reaction times, and lowered detection thresholds measured from psychometric curves. In a filter task, the spatial cue indicated the location of the relevant visual event, and we found that mice could be trained to ignore irrelevant but otherwise identical visual events at uncued locations. Together, these results demonstrate that mice exhibit visual selective attention, paving the way to use visual paradigms in mice to study the genetic and neuronal circuit mechanisms of selective attention.

Acknowledgement: National Eye Institute Intramural Research Program at the National Institutes of Health

61.12, 8:30 am **A node for hemi-spatial neglect in macaque temporal cortex** Amarender R Bogadhi[1](amarender.bogadhi@nih.gov), Leor N Katz[1], Anil Bollimunta[1], Richard J Krauzlis[1]; [1]Laboratory of Sensorimotor Research, National Eye Institute, National Institutes of Health

Studies of hemi-spatial neglect in humans have emphasized fronto-parietal and temporal cortical contributions to spatial attention along with several sub-cortical areas. Fronto-parietal and sub-cortical areas causally contribute to covert spatial attention in monkeys, but evidence that temporal cortex contributes to covert spatial attention is lacking. Here, we show that reversible inactivation of functionally identified mid-STS region during a covert attention task leads to performance deficits akin to hemi-spatial neglect. We trained monkeys in a covert attention task consisting of "Attend" and "Ignore" conditions. A central cue instructed the animal to either attend or ignore peripheral motion stimuli. The task of the animal was to maintain central fixation and to report the relevant stimulus change event by releasing a lever to get a juice reward. In Attend trials, the relevant event was the peripheral motion-direction change. In Ignore trials, the relevant event was dimming of the central fixation point while the peripheral motion-direction change was irrelevant and should be ignored. Pairing fMRI with reversible inactivation of Superior Colliculus (SC) during the covert attention task, we identified the mid-STS region (aFST) whose attention-related modulation was reduced during SC inactivation. To test if this region contributes causally, we reversibly inactivated aFST by injecting 4 – 6µl of muscimol during the covert attention task. We performed a total of 6 muscimol and 3 saline/sham control experiments. Reversible inactivation of aFST led to significant performance deficits in detecting stimulus changes in the contralateral hemi-field during the Attend condition. Furthermore, control experiments showed that the performance deficits for the contralateral stimulus cannot be fully explained by the effect of muscimol on motion processing. Our results show that inactivation of mid-STS region (aFST) leads to attention-related deficits akin to hemi-spatial neglect, hence revealing a temporal cortical node for hemi-spatial neglect in monkeys during a covert attention task.

61.13, 8:45 am **The N2pc does not reflect a shift of covert spatial attention** Joshua J Foster[1](joshuafoster@uchicago.edu), Emma M Bsales[1], Edward Awh[1]; [1]Department of Psychology, University of Chicago

The N2pc is a transient negative deflection in EEG activity that is observed contralateral to visually selected stimuli. While the N2pc provides a sensitive index of visual selection, it remains unclear whether it reflects a shift of attention towards the selected stimulus, or cognitive operations that occur after spatial attention has been deployed. Kiss and colleagues (2008) demonstrated that the N2pc component was unaffected when subjects were cued to the relevant hemifield in advance, suggesting that it may not reflect a shift of attention. However, because observers can orient attention precisely within a hemifield, the N2pc may still have been driven by reorienting of attention within the relevant hemifield. To resolve this issue, we manipulated whether or not covert attention was deployed to the target location prior to the onset of a search array, and we used ongoing alpha oscillations to verify the specific locus of covert selection prior to target onset. In line with past work, alpha activity precisely tracked the selected location following informative cues, but showed no evidence of spatial orienting following neutral cues. Nevertheless, both conditions exhibited a clear target-locked N2pc with equal amplitude, suggesting that the N2pc does not reflect a shift of attention to the target. An attractive alternative explanation is that the N2pc reflects target individuation, the segregation of selected items from the background and other items in the display (Ester et al., 2012; Mazza & Caramazza, 2015). Interestingly, while N2pc amplitude was equivalent following informative and neutral cues, the onset of both the N2pc and the lateralized readiness potential (LRP) – an electrophysiological signature of response preparation – were earlier following informative cues (16 and 50 ms, respectively). Thus, our findings also show that spatial precues speed the accumulation of response-related information, rather than just facilitating the spatial selection of targets.

61.14, 9:00 am **Theta-band oscillations track the time course of attentional suppression** Tobias Feldmann-Wüstefeld[1](tobiasfw@uchicago.edu), Edward Awh[1]; [1]University of Chicago

A growing body of evidence suggests that in addition to prioritizing relevant information, active suppression of irrelevant information contributes to visual selective attention. Lateralized event-related potentials (ERPs) like the N2pc and PD component can be used to compare attentional processes between hemifields. However, inverted encoding models (IEM) that make use of multivariate signals can track the locus of attention in a more fine-grained manner (Foster et al. 2017; Fahrenfort et al., 2016). Here, we used this approach to track visual attention while subjects searched for a specific target shape in a display that also contained a color singleton distractor (Theeuwes, 1992). In line with past work, the scalp topography of alpha activity allowed tracking of covert orienting to both target and distractor locations, reflecting attention deployment and attentional capture, respectively. Most importantly, a similar analysis of activity in the theta band revealed below-baseline channel activity at the position of color distractors and during a time window that overlapped the PD component indexing distractor suppression. These findings suggest that theta band activity tracks the active suppression of locations occupied by the irrelevant color singletons. In line with this possibility, responses to targets stimuli were slower when the color singleton overlapped the position of the target compared to when no distractor was presented at all. In sum, our results suggest that the topography of theta band activity may provide a precise neural index of the position and timing of distractor suppression.

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61.15, 9:15 am **The visual representation of templates for rejection** Reshanne Reeder[1](reshanne.reeder@ovgu.de), Christian N. L. Olivers[2], Stefan Pollmann[1,3]; [1]Department of Experimental Psychology, Institute of Psychology, Otto-von-Guericke University, Magdeburg, Germany, [2]Department of Experimental and Applied Psychology, and Institute for Brain and Behavior, Vrije Universiteit, Amsterdam, The Netherlands, [3]Center for Behavioral Brain Sciences, Magdeburg, Germany

The concept of a "template for rejection", or the activation of distractor visual information to benefit subsequent target detection, has been hotly contested in recent years. Is a distractor enhanced like a target with an additional "tag" that it should be rejected once it has been detected during search? Or is it already inhibited during the preparatory period, biasing attention towards other features (including the target) of the upcoming search display? Here, subjects were required to detect a target in an array containing four items of one color and four items of a second color, while undergoing fMRI. One of the two colors was cued beforehand as positive ("the target will appear in this color"), negative ("only distractors will appear in this color"), or neutral ("this color will not appear in the search display"). We used representational similarity analysis within different regions of visual cortex to investigate how distinctly these colors are represented in preparation for search, given the advanced knowledge that they provide information on targets, distractors, or neither. Results revealed more distinct patterns following positive cues compared to negative and neutral cues, whereas negative and neutral cues did not show significantly different levels of color representation distinctiveness. This study is the first to provide evidence that visual features of distractors are represented less distinctly in visual cortex compared to targets during preparation for search, supporting the hypothesis that searchers can strategically use a template for rejection that is functionally distinct from a target template.

Acknowledgement: This project was supported by Open Research Area grants DFG PO 548/16-1 to SP and NWO 464-13-003, NL, and European Research Council Consolidator grant ERC-CoG-2013-615423 to CO.

61.16, 9:30 am **Statistical learning shapes distractor suppression** Jan Theeuwes[1,2](J.Theeuwes@psy.vu.nl), Benchi Wang[1,2], Joram van Driel[1,2], Cristian N.L. Olivers[1,2]; [1]Department of Experimental and Applied Psychology, Vrije Universiteit Amsterdam, [2]Institute Brain and Behavior Amsterdam (iBBA)

Even though traditionally attentional control is considered to be the result of the interaction between top-down and bottom-up mechanisms, Awh, Belopolsky and Theeuwes (2012, TICS) have suggested a theoretical framework in which this division is argued to be incomplete. They argued that the history of attentional deployments can elicit lingering selection biases, which are unrelated to top-down goals or the physical salience of items. Whereas previous work has primarily focused on target selection, here we investigated whether implicitly learned statistical regularities can influence distractor processing. We used the additional singleton task in which participants search for a salient shape singleton while ignoring a color distractor singleton. This color distractor was systematically presented more often in one location than in all other locations. Using measures of behavior, we demonstrate that for this high-probability location, both the amount of attentional capture by distractors and the efficiency of selecting the target were reduced. Measures of brain activity, specifically the Pd (distractor positivity) and N2pc components of the event-related potential, were used to track the allocation of attention and suppression to lateralized positions in the arrays. We find evidence for a Pd-like component for the high probability location, even though both the target and the distractor were presented on the vertical meridian (top and bottom) and thus could not themselves elicit a lateralized component in the ERP. When the distractor was presented at the lateralized high probability location, this also generated a Pd, while a distractor presented at a low probability location generated an N2pc. The same was found for when the target was presented at the high versus low lateralized probability location. We interpret these findings as evidence that spatial statistical regularities influence distractor processing through inhibition of high probability locations.

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61.17, 9:45 am **Probing mixed selectivity with fMRI voxel analysis** Yaoda Xu[1](yaodaxu@wjh.harvard.edu), JohnMark Taylor[1], Maryam Vaziri-Pashkam[2]; [1]Psychology Department, Harvard University, [2]Laboratory for Brain and Cognition, NIH

Past research in macaque neurophysiology has identified mixed-selectivity neurons that respond to combinations of variables, such as task and stimulus type, in a way that is a nonlinear function of the variables considered individually. However, the prevalence of these neurons in human cortex remains largely unexplored. If neurons with mixed selectivity are distributed heterogeneously within a brain region at a spatial scale detectable by fMRI, then we should be able to measure mixed selectivity at the voxel level with fMRI, leveraging the whole-brain coverage that fMRI affords. Here, we tested the feasibility of this approach and compared the magnitude of mixed-selectivity coding across human occipital, parietal and frontal regions. Specifically, we examined data from four experiments in which human participants engaged in several tasks upon exemplars from eight object categories. In three of the experiments, participants performed a oneback task on either the shape or color of the exemplar, varying the conjunction strength between shape and color across experiments. In a fourth experiment, participants performed either a oneback or oddball task on the exemplar. In all four experiments, stimuli were equated between tasks, allowing us to model main effects of task and stimulus category, and their interaction, on voxel responses. Across all four experiments, we found that voxel responses in the frontoparietal regions were significantly better explained by task/stimulus interaction terms than the early visual and ventral regions, reflecting the presence of nonlinear mixed selectivity neurons in frontoparietal regions that enable them to effectively integrate task and stimulus information for flexible behavior. These findings demonstrate the feasibility of using fMRI to examine mixed-selectivity noninvasively in the human brain.

Multisensory

Wednesday, May 23, 8:15 - 10:00 am, Talk Room 2

Moderator: Loes van Dam

61.21, 8:15 am **Tracking tactile braille brain responses in space and time** Santani Teng[1,2](santani@mit.edu), Radoslaw Cichy[3], Dimitrios Pantazis[4], Aude Oliva[1]; [1]CSAIL, Massachusetts Institute of Technology, [2]Smith-Kettlewell Eye Research Institute, [3]Dept. of Education and Psychology, Free University of Berlin, [4]McGovern Institute for Brain Research, Massachusetts Institute of Technology

When read by blind individuals, tactile braille characters undergo a cascade of transformations over space, time, and representational format. This processing stream is known to recruit typically visual cortical regions as it changes somatosensory dot patterns to semantically meaningful representations. To elucidate the poorly understood spatiotemporal, as well as representational, dynamics of this reorganized functional network, we applied multivariate decoding and representational similarity analysis to magnetoencephalography (MEG) recordings of blind participants' brain responses to braille letters presented to the finger pads. Following previous work suggesting largely idiosyncratic patterns in a sample of braille readers, we presented single alphabetical braille letters in random order during MEG recording of early-blind, braille-proficient individuals in multiple sessions. Subjects performed a 1-back task in which they passively read presented letters and responded via button press to occasional repeated trials, which we excluded from further analysis. To increase the spatial specificity of the signal, we extracted left and right sensorimotor, early "visual" (EVC), and fusiform regions of interest (ROIs) from individual MRI anatomical scans. We then used MVPA to decode letter identity pairwise over time and construct a representational dissimilarity matrix (RDM) of pairwise relationships between letter signals for each time point. Earliest and strongest decoding signals were found specific to the sensorimotor ROIs contralateral to the stimulated finger. EVC and fusiform ROIs showed later onsets and noisier, more sustained representations. Early representational patterns as operationalized by model RDMs are consistent with a sensitivity to low-level letter complexity (e.g., number of dots) in somatosensory cortex, while later representations in downstream ROIs exhibited weaker adherence to this

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scheme. Our results offer a window into the sensory-to-semantic transformation of braille stimuli as well as a model for investigating the dynamics of crossmodal plasticity in sensory loss generally.

Acknowledgement: Vannevar Bush Faculty Fellowship (Office of Naval Research Grant N00014-16-1-3116) to A.O. McGovern Institute Neurotechnology Program to A.O. and D.P..

61.22, 8:30 am **Cross-modal Plasticity After Early Blindness Co-opts Persisting Visual Archetecture.** Tristram Savage[1](savaget@uw.edu), Ione Fine[1], Fang Jiang[2]; [1]Department of Psychology, University of Washington, Seattle, USA, [2]Department of Psychology, Center for Integrative Neuroscience, University of Nevada, Reno, USA

It is well established that hMT+ shows responses to auditory motion in early blind individuals not seen in sighted controls. Here, we examine whether these auditory responses co-opt residual visual architecture by examining interactions between visual and auditory motion in a sight-recovery subject MM. As a result of early blindness, MM still shows robust cross-modal responses to auditory motion in hMT+. MM acquired vision in adulthood; despite severe losses in acuity, MM has no known deficits in his ability to process visual motion, and shows normal hMT+ responses to visual motion. Methods: In the behavioral task, subjects reported the direction (left/right) of a moving dot field that varied in motion coherence. Simultaneously, we presented a task-irrelevant auditory motion stimulus, whose left/right direction was random with respect to the visual motion direction. Two separate fMRI experiments examined hMT+ responses. (1) Using multivoxel pattern classification, we tested whether visual direction of motion could be classified with an auditory motion training set and vice versa. (2) We compared BOLD univariate responses for 0.5s auditory and visual motion stimuli presented in-phase vs. anti-phase. Results: Behaviorally, the direction of auditory motion biased the perceived direction of visual motion in MM but not controls. Using fMRI, both experiments found evidence for interactions between auditory and visual motion directional responses within hMT+ in MM, but not controls. (1) The direction of auditory motion could be successfully classified based on the pattern of BOLD responses to a visual motion stimulus, and vice versa. (2) BOLD responses were larger when visual and auditory stimuli were presented anti-phase vs in-phase. Thus, the cross-modal plasticity induced by early blindness in area hMT+ seems to be scaffolded upon residual visual motion architecture, and in the case of MM, this seems to have perceptual consequences.

Acknowledgement: EY-014645, EY023268, P20 GM103650

61.23, 8:45 am **Humans Combine a New Auditory Cue to Distance with Vision After Less Than 3 Hours of Training** Marko Nardini[1](marko.nardini@durham.ac.uk), James E Negen[1], Lisa Wen[1], Lore Thaler[1]; [1]Dept of Psychology, Durham University, UK

Humans are highly effective at dealing with noisy, probabilistic information. One hallmark of this is Cue Combination: combining two independent noisy sensory estimates to increase precision beyond the best single estimate. Surprisingly, this is not achieved until 10-12 years of age (Gori et al, Curr Biol 2008; Nardini et al PNAS 2010), despite other multisensory skills appearing in infancy. It is unclear if lack of cue combination in children is due to maturation or experience with specific cues. The "experience" account predicts that adults learning new cues would fail to combine them for many years. To test this, we asked 12 adults in a virtual reality environment to judge distance to a whale hidden under the sea, using both vision and a novel audio cue to distance akin to echoes used in human echolocation (Thaler & Goodale, WIREs Cogn Sci 2016). Within two hour-long sessions, participants successfully learned to judge distance using the novel audio cue (correlation coefficients > .80, all ps < .001). In subsequent sessions we compared variable error in trials with only one cue (visual, novel audio) and those with both cues together. We found significantly lower variable error with both cues versus the best single cue, as expected under cue combination (averaging). This pattern of results persisted even when the novel cue was provided using a new auditory frequency, and when we changed the cues' relative reliabilities. Further, when relative reliabilities changed we also observed a re-weighting of cues. This supports the idea that participants combined cues, rather than having learned a decision rule with specific stimuli. In conclusion, our results suggest that humans develop general-purpose cue combination abilities as they mature. The discovery that people can immediately integrate new signals into their existing repertoire further suggests an optimistic outlook on substituting or augmenting human senses.

Acknowledgement: Supported by grant ES/N01846X/1 from the UK Economic and Social Research Council

61.24, 9:00 am **The mapping and reconstruction of the brain's mind eye in the absence of visual experience: a population receptive field mapping of soundscape space** Shir Hofstetter[1](shirhofs@gmail.com), Wietske Zuiderbaan[2], Serge Dumoulin[2,3], Amir Amedi[1]; [1]Medical Neurobiology, Hebrew University of Jerusalem, [2]The Spinoza Centre for Neuroimaing, [3]Experimental Psychology, Utrecht University

Studies showed that blind participants trained in visual-to-auditory sensory substitution devices (SSDs) were able to recognize various 'visual' objects and even body shapes and faces. Correspondingly they also specifically activated many of the known categories in the high-order visual streams1. But how is this learned experience integrated in the brain? Does the visual-to-auditory input follow similar organizational principles as the natural senses? Here we studied a proficient EyEMusic-SSD2 congenitally blind user using population receptive field (pRF) mapping3, a method for imaging visual retinotopic maps. The EyEMusic-SSD algorithm reads the image from left to right and forms a soundscape of the image where the X and Y axes are represented by time and pitch in pentatonic-scale, respectively2. Full tonotopic maps of musical pitch-elevation (y axis) were found in bilateral A1, showing organized maps of the EyeMusic's notes. Moreover, topographical maps of the soundscape field were found in the right lateral occipital (LO), right medial occipital cortex, and right parietal-occipital cortex (PO). Full topographic maps of timing of the stimuli (x axis) were shown in the same regions in the right LO and right PO. Notably, in the right PO, the maps of the two axes overlapped. Conceptually, this proposes that the learned soundscape field may be analyzed in a similar way to how the two dimensions of retinotopy, eccentricity and polar angle, span the visual field. We were also able to reconstruct and predict the perceived stimuli in the soundscape-field. This case study suggests that in adulthood novel topographic maps can develop following extensive training in novel topographic sensory experiences. References 1. Amedi, A. et al. Trends Cogn. Sci., 2017 2. Abboud, S. et al. Restor. Neurol. Neurosci. 2014 3. Dumoulin, S.O. et al. Neuroimage, 2008

Acknowledgement: European Research Council grant (grant number 310809)

61.25, 9:15 am **When visuomotor adaptation fails, 3D perception changes** Evan Cesanek[1](evan_cesanek@brown.edu), Fulvio Domini[1]; [1]Department of Cognitive, Linguistic, & Psychological Sciences, Brown University

Visuomotor adaptation is often sufficient to resolve movement errors caused by sensorimotor perturbations, but certain kinds of perturbations cause errors that cannot be resolved by adaptation. We hypothesized that these unresolvable errors would be effective in changing 3D perception. In two experiments, participants provided perceptual estimates of stereo-texture surface slants before and after repetitive visuomotor interactions with cue-conflict surfaces where haptic feedback was always consistent with texture. The visuomotor task was to reach toward the target surfaces with a precision grip, orienting the grip so that the finger and thumb would make contact simultaneously. In Experiment 1, participants aimed at three different cue-conflict surfaces, each having a texture-specified slant 30° deeper than its stereo-specified slant. Terminal grip orientations initially targeted the intermediate perceived slants, but were adjusted toward the consistently deeper physical slants over time, demonstrating successful visuomotor adaptation. By including a washout phase where the cue-conflict slants were replaced with perceptually matched cue-consistent slants, we verified that the change was due to standard visuomotor adaptation, as opposed to an increased weight on texture information for grip orientation. As predicted for successful adaptation, we observed no change in slant perception. In Experiment 2, we presented a variety of cue-conflict surfaces. For some, the haptically reinforced slant was flatter than the perceived slant; for others, it was deeper than perceived. Due to interference between these opposing perturbations, visuomotor adaptation failed to resolve the movement errors. As predicted for unsuccessful adaptation, the pattern of changes in slant perception for the cue-conflict surfaces matched the pattern of experienced movement errors. Addition-

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ally, we found that cue-consistent surfaces were perceived as flatter. Our findings show that when limitations on visuomotor adaptation allow movement errors to persist, 3D visual perception changes. This suggests that visuomotor and 3D perceptual processes share the goal of supporting accurate movement.

61.26, 9:30 am **A common cause in the phenomenological and sensorimotor correlates of body ownership** Majed J Samad, Cesare Parise[1,2], Sean Keller[1], Massimiliano Di Luca[1,3]; [1]Oculus Research, Facebook, [2]University of Bielefeld, [3]University of Birmingham

The feeling that our limbs belong to our body is at the core of bodily self-consciousness. Over the years, limb ownership has been assessed through several types of measurements, including questionnaires and sensorimotor tasks assessing the perceived location of the hand with a visual-proprioceptive conflict. Some studies report a correlation between the phenomenological and sensorimotor measures, whereas others report no relationship. This inconsistency dispels a unified operational definition of limb ownership. We sought to jointly record these two measurements to assess whether they originate from the same process. To that end, we used state-of-the-art hand tracking technology in virtual reality to induce ownership over a virtual limb while we parametrically manipulated spatial and temporal incongruences. Participants reported the subjective ownership and pointed to a target without seeing their hand to assess perceived hand location. Results show a surprisingly tight correlation between phenomenological and sensorimotor measures. We frame limb ownership as a multisensory integration problem, whereby the brain computes the probability that visual and proprioceptive signals have a common cause -- and thus that the visually presented hand belongs to one's body -- and based on this determines the perceived hand location considering the reliability of the sensory signals. The outcome of the computation thus determines both the position of the hand and the strength of the ownership on which the subjective feeling should be based. We show that a Bayesian Causal Inference model closely captures human responses in both tasks, reconciling a fragmented literature and suggesting that body ownership can be well explained by a normative framework that has also been shown to account for a variety of other multisensory phenomena.

61.27, 9:45 am **Visual and tactile working memory stores have independent capacity limitations** Tobias Katus[1](t.katus@gmx.de), Martin Eimer[1]; [1]Department of Psychological Sciences, Birkbeck, University of London, United Kingdom

Whether the capacity of working memory (WM) is limited by a central resource and/or mechanisms that are shared across sensory modalities is controversial. To address this question, we conducted a dual-task experiment where tactile and visual WM load were varied separately (1, 2 or 3 items per modality), and memory was tested unpredictably for vision or touch on each trial. The visual and tactile contralateral delay activity (CDA and tCDA components) were measured over visual and somatosensory cortex during WM maintenance. Increasing memory load in vision or touch produced strictly modality-specific effects. The CDA increased for visual load increments from 1 to 2 and 3 items, and the tCDA increased with 1 versus 2 tactile items, but showed no further enhancement for 3 items. Critically, neither did tactile load influence the visual CDA, nor did visual load modulate the tCDA. There were also no crossmodal costs of increasing load in the other modality on visual and tactile WM performance. An additional behavioral study found crossmodal interference when WM load was increased beyond the capacity limits of tactile and visual stores, with impaired performance when 12 multisensory items had to be maintained relative to 6-item single-task baselines. This interference was uncorrelated with individual differences in visual or tactile WM capacity, but strongly predicted individual differences in tests of executive control functions involved in task/response selection (Stroop-, Simon-, and Psychological Refractory Period tasks). This suggests that crossmodal interference in WM tasks is not the result of shared capacity limitations across modalities, but instead reflects dual-task coordination costs. Overall, these experiments show that tactile and visual WM representations are maintained by modality-specific mechanisms with independent capacities, and that crossmodal interference arises primarily at the level of domain-general central executive processes that control these modality-specific stores.

Acknowledgement: Leverhulme Trust (Grant RPG-2015-370)

Faces: Neural mechanisms

Wednesday, May 23, 11:00 am - 12:45 pm, Talk Room 1

Moderator: Daniel Baldauf

62.11, 11:00 am **Amygdala damage eliminates monkeys' viewing preference for real and illusory faces.** Jessica Taubert[1](jesstaubert@gmail.com), Susan G Wardle[2], Molly Flessert[1,3], Benjamin M Basile[4], Elissa Koele[1], Clarissa James[1], Elisabeth A Murray[4], Leslie G Ungerleider[1]; [1]Section on Neurocircuitry, Laboratory of Brain and Cognition (LBC), NIMH, USA, [2]Department of Cognitive Science, Macquarie University, Sydney, Australia, [3]Department of Psychology, Language Research Center, Georgia State University, [4]Section on Neurobiology of Learning and Memory, Laboratory of Neuropsychology (LN), NIMH, USA

Rhesus monkeys (Macaca mulatta), like humans, look longer at images of faces than at non-face objects in a viewing preference task. We recently demonstrated that monkeys also exhibit a viewing preference for photographs of objects that elicited face pareidolia in human subjects over photographs of similar objects that did not elicit illusory faces. We interpreted this preference as evidence that monkeys experience face pareidolia, the illusion of facial structure in an otherwise inanimate object (Taubert et al., 2017, Current Biology). Here, we evaluated viewing preferences for face stimuli, both real and illusory, in three monkeys with selective, bilateral amygdala lesions. The amygdala is thought to be part of the extended face-processing system in the primate brain, but its exact role in face perception is not well understood. In this experiment, we used three types of stimuli: 15 conspecific faces, 15 illusory faces and 15 non-face objects. We presented each subject (N = 3) with all possible pairs of these 45 images, resulting in 1980 trials. Each pair was presented for four seconds. We collected two dependent variables: how long a subject looked at each of the images in a given pair, and where they fixated on each image. Unlike normal monkeys, who show robust preferences for both real and illusory faces, monkeys with selective amygdala damage showed no preference for real faces over non-face objects or for illusory faces over non-face objects. Further, whereas normal monkeys show classic face viewing patterns prioritizing discrete facial features such as the eyes and mouth, monkeys with amygdala damage showed disorganized viewing patterns. Our results thus indicate that the amygdala plays a critical role in spontaneous behavior towards face stimuli (i.e. the speed and ease with which we detect faces, and prioritize them over non-face objects).

62.12, 11:15 am **A face is more than just the eyes, nose, and mouth: fMRI evidence for the role of external face features in face recognition** Frederik S Kamps[1](fkamps@emory.edu), Ethan J Morris[1], Daniel D Dilks[1]; [1]Department of Psychology, Emory University

What is a face? Intuition, along with abundant behavioral and neural evidence, indicates that internal features (e.g., eyes, nose, mouth) are critical for face recognition, yet some behavioral work suggests that external features (e.g., hair, jawline, shoulders) may likewise be processed as part of the face. Here we addressed this question by asking how the brain represents isolated internal and external face features. We tested three predictions in particular. First, if a "face" includes both internal and external face features, then these features should activate similar neural systems. Consistent with this prediction, we found highly overlapping activation for internal and external face features within face-selective cortex. Second, if a "face" includes both internal and external face features, then face-selective regions should respond strongly and selectively to both internal and external face features. Consistent with this prediction, we found strong and selective responses to both internal and external features in four face-selective regions, including the occipital face area (OFA), fusiform face area (FFA), posterior superior temporal sulcus (pSTS), and anterior temporal lobe (ATL). Third, if a face includes both internal and external features, then face-selective regions should perform the same computations across both features. Consistent with this prediction, we found that OFA and pSTS extract the "parts" of both internal and external face features, while FFA and ATL represent the coherent arrangement of both internal and external face parts. Taken together, these results provide strong neural evidence that external features, like internal features, constitute a face.

Acknowledgement: National Eye Institute grant T32EY7092 (FK), Emory University (DD)

62.13, 11:30 am **Dissociating unfamiliar and familiar face discrimination processes over the course of natural familiarization** Alison C. Campbell[1](campbel1@uvic.ca), James Tanaka[1]; [1]University of Victoria, Canada

Whereas most studies in the face processing literature have focused on either the perception of unfamiliar faces or the recognition of familiar faces, far fewer studies have investigated the processes by which an unfamiliar face becomes familiar. Here, we examined the emergence of face familiarity as a result of natural socialization. The brain responses of student participants enrolled in a small seminar course were recorded using fast periodic visual stimulation (FPVS) before meeting (pre-familiarization) and after 8-weeks of socialization (post-familiarization). Experimental stimuli consisted of participant and non-participant faces displaying a range of poses and expressions. At each test time, seminar participants viewed a stream of non-participant faces presented at 6 Hz with a participant face embedded every 7 images (0.86 Hz). In the converse condition, a 6 Hz stream of participant faces was embedded with a non-participant face every 7 images (0.86 Hz). Pre-familiarization, when peer and non-peer faces are equally unfamiliar, the visual stimulation in both conditions elicits a response at 6 Hz related to processing unfamiliar faces. However, after participant faces had become familiarized, effects pertaining to the differential familiarity of participant and non-participant faces began to emerge. In the post-familiarization test, the presentation rate of participant faces (0.86Hz) in the first condition elicited greater amplitudes approaching significance in high level visual areas only, reflecting increased familiarity of participant faces. By contrast, when participant faces are no longer unfamiliar, brain responses reflecting unfamiliar face processing should emerge in the alternative condition at the presentation rate of non-participant faces (0.86 Hz). Consistent with this, a robust increase in amplitudes at the 0.86 Hz frequency was observed post-familiarization, but in fronto-central sites only. Thus, by manipulating the personal familiarity of faces, we find differential brain regions involved in familiar compared to unfamiliar face discrimination

Acknowledgement: Natural Sciences and Engineering Research Council of Canada (NSERC)

62.14, 11:45 am **Distinct neural processes for the perception of familiar versus unfamiliar faces along the visual hierarchy revealed by frequency tagging** Elliot Collins[1,2](egcollin@andrew.cmu.edu), Amanda Robinson[1], Marlene Behrmann[1]; [1]Carnegie Mellon University, Center for Neural Basis of Cognition, [2]University of Pittsburgh

Humans easily recognize faces, despite the complexity of the task and the visual system which underlies it. Different spatial regions, including both core and extended face networks, and distinct temporal stages of processing have been implicated in face recognition and there is ongoing controversy regarding the extent to which the mechanisms for recognizing a familiar face differ from those of an unfamiliar face. Here, we used electroencephalogram (EEG) and frequency tagging, a high signal-to-noise approach, and whole brain decoding methods to elucidate the processes that subserve familiar and unfamiliar face recognition. Familiar and unfamiliar faces were presented periodically at 15Hz, 6Hz and 3.75Hz either upright or inverted in separate blocks, with the rationale that faster frequencies allow shorter processing times per image. Decoding of 15 Hz trials, which likely evince early visual processing, revealed similar classification for upright and inverted faces for familiar and unfamiliar. At 6 Hz, decoding familiarity was more accurate for upright compared with inverted faces. Decoding face orientation (upright versus inverted) was more accurate for unfamiliar than familiar faces, indicative of view-invariant pattern recognition associated with familiar faces and implicating the core face network. Finally, at 3.75 Hz, there were no main effects of familiarity, but decoding showed significant correlation with individual face familiarity ratings, suggesting that this slow frequency reflected higher-level cognitive aspects of familiarity processing. These results reveal fundamentally distinct temporal stages of processing, only the slowest of which directly correlates with personal familiarity. These findings may reflect a non-linearity in brain activity between early and later stages of processing, as documented by Landi & Freiwald (2017).

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62.15, 12:00 pm **Symmetrical Viewpoint Representations in Face-Responsive Regions of the Human Brain Convey an Advantage in Face Learning** Tessa R Flack[1](tessa.flack@durham.ac.uk), Richard J Harris[2], Andrew W Young[3], Timothy J Andrews[3]; [1]Department of Psychology, Durham University, Durham, UK, [2]School of Psychology, University of Leeds, Leeds, UK, [3]Department of Psychology, University of York, York, UK

Learning new faces is crucial for effective social interaction. Although we are able to recognise familiar faces from a variety of viewpoints, viewpoint-invariance is not well understood. Responsiveness to mirror-symmetric views of faces has been proposed as a key computational step in achieving viewpoint-invariance. The aim of this study was to measure responses to symmetric views of real human faces in face-responsive regions of the human brain and ask whether these convey an advantage in the perception and recognition of faces. In Experiment 1 (n=20), we used fMRI to measure responses in face-responsive regions while participants viewed images of faces at different viewpoints (0^o, 45^o, 90^o, 135^o, 180^o). Patterns of response to symmetrical views of the face (45^o & 135^o or 0^o & 180^o) were more similar than asymmetrical views (e.g. 0^o & 45^o or 135^o & 180^o) in the FFA and pSTS. In Experiment 2 (n=20) participants made perceptual similarity judgements to pairs of face images. Similar to the fMRI data, images with symmetrical viewpoints were reported as being more similar to each other than non-symmetric views. In Experiment 3 (n = 19), we asked whether this sensitivity to symmetric views would convey an advantage on an identity matching task for unfamiliar faces. We found performance on the unfamiliar face matching task was not significantly better for symmetric images. In Experiment 4 (n = 48), we asked whether symmetrical views convey an advantage when learning new faces. Using a recognition memory paradigm, participants learned new faces at different viewpoints. Performance was best when tested in directions symmetrical to the learning direction, compared to viewpoints that were asymmetric. Together these results demonstrate that the viewpoint symmetry found in face-responsive regions of the brain reflects the perceptual experience of participants and conveys an advantage when we learn new facial identities.

62.16, 12:15 pm **Top-down attention in the face-processing network: an MRI-guided MEG study using multiple simultaneous frequency tags** Daniel Baldauf[1](baldauf@mit.edu), Eelke de Vries[1]; [1]Center for Mind/Brain Sciences (CIMeC), University of Trento, Italy

We recorded magnetoencephalography (MEG) using a frequency-tagging paradigm with compound face stimuli that allowed for independently frequency-tagging various parts of a face (eyes, mouth) as well as changes in facial identity. Our MRI-guided MEG analyses revealed that different sub-nodes of the human face-processing network were tagged differentially according to their functional specialization. Whereas the occipital face area (OFA) was most responsive to the frequency, at which face parts (e.g., the mouth) changed, the fusiform face area (FFA) was selectively entrained by the rhythmic updating of facial identity. Face patches in the superior temporal sulcus (STS) were mostly entrained by rhythmic changes in the eyes region. Furthermore, top-down attention to the mouth, eyes, or identity of the face selectively modulated the neural processing in the respective area (i.e., OFA, STS, or FFA, respectively), closely resembling behavioral cue validity effects observed in the participants' reaction time and detection rate data. Our results allow new insights in the hierarchical organization of the occipital face processing network and the flow of information among its components. Further, our results illuminate how top-down attention biases the visual processing of different aspects and dimensions within a single face-object, at various stages of the involved visual processing hierarchy.

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62.17, 12:30 pm **Serial dependence fluctuates at alpha rhythms** Yuki Murai[1,2](ymurai@berkeley.edu), Mauro Manassi[1], Bill Prinzmetal[1], Kaoru Amano[3,4], David Whitney[1]; [1]Department of Psychology, University of California, Berkeley, [2]Japan Society for the Promotion of Science, [3]Center for Information and Neural Networks, National Institute of Information and Communications Technology, [4]Graduate School of Frontier Biosciences, Osaka University

To perceive the world as stable, our visual system tries to estimate it optimally based on the current sensory input and the past information. Serial dependence is a representative example of how the past forms the current percept: the perception of a stimulus is biased towards previously seen stimuli (Fischer & Whitney, 2014; Cicchini et al., 2014). In the present study, we investigated neural correlates of serial dependence using EEG. Because previous studies have demonstrated that alpha oscillations play an important role in visual encoding (Jensen et al., 2012), and the stimulus encoding may be an important factor in perceptual serial dependence, we hypothesized a link between alpha oscillations and serial dependencies in perception. In an experiment, a test face drawn from a continuous morph of facial identities was briefly presented, and then subjects adjusted a response face to match the test face. EEG signals were recorded while subjects performed the task. In the analysis, we sorted trials based on the phase of alpha oscillations at the precise moment the test face appeared, and calculated the magnitude of serial dependence (i.e., how much the current face appears pulled toward the faces seen in previous trials) separately for trials with different alpha phases. We found the serial dependence fluctuated periodically, depending on the alpha phase in frontal and occipital sites. In occipital sites, the serial dependence at 0 deg phase was 4-6 times larger than the serial dependence at 180 deg phase, and this relation was reversed in frontal sites. Permutation tests confirmed the significance of the observed periodic fluctuation in serial dependence. These results suggest that alpha oscillations are involved in the encoding of face information and modulate serial dependence in face perception. Serial dependence might reflect perceptual ambiguity of the stimulus, which could depend on the phase of alpha oscillations.

Scene Perception

Wednesday, May 23, 11:00 am - 12:45 pm, Talk Room 2

Moderator: Miguel Eckstein

62.21, 11:00 am **The Parahippocampal Place Area is involved in scene categorization, not landmark recognition** Andrew S Persichetti[1](apersic@emory.edu), Daniel D Dilks[1]; [1]Department of Psychology, Emory University

There is a rift in the human scene processing literature. While several neuroimaging studies have argued that the parahippocampal place area (PPA) is involved in landmark recognition (i.e., recognizing a particular place or stable object in the environment), evidence from many other studies suggests otherwise. Based on results from the latter studies, we propose that PPA is not well suited to recognize landmarks in the environment, but rather is involved in recognizing the category membership of scenes (e.g., recognizing a scene as a coffee shop). We used fMRI multi-voxel pattern analysis to test this hypothesis. We scanned participants after they learned the layout of a virtual town that consisted of a park square surrounded by eight buildings. There were two buildings on each corner of the town. Each building belonged to a particular category: two coffee shops, two hardware stores, two gyms, and two dentist offices. Importantly, the locations of any two buildings belonging to the same category were dissociable from the category information (e.g., one gym was in the northeast corner of the town, while the other was in the southwest corner). If PPA represents landmark information, then it must be able to discriminate between two places of the same category, but in different locations of town. By contrast, if PPA represents general category information, then it will not represent the location of a particular place, but only the category of the place. As predicted, we found that PPA represents two buildings from the same category, but in different locations, as more similar than two buildings from different categories, but in the same location, while another scene-selective region of cortex, the retrosplenial complex (RSC), showed the opposite pattern of results. Such a double dissociation suggests distinct neural systems selectively involved in navigation and categorization of scenes.

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62.22, 11:15 am **The Foreground Bias: Initial scene representations dominated by foreground information** Monica S. Castelhano[1](monica.castelhano@queensu.ca), Suzette Fernandes[1]; [1]Department of Psychology, Queen's University

Researchers have often posited that scene representations have a hierarchical structure with background elements providing a scaffold for more detailed foreground elements (Brooks, Rasmussen, & Hollingworth, 2010; Davenport & Potter, 2004; Henderson & Hollingworth, 1999). To further investigate scene representation and the role of background and foreground information, we introduced a new stimulus set: chimera scenes, which have the foreground set of objects belonging to one scene category, and the surrounding background structure belonging to another category. Across three experiments, we examined the contribution of each scene plane to the initial understanding of scenes when rapidly presented. In the first experiment, participants categorized either Normal or Chimera scenes (i.e., scenes with background and foreground from different semantic categories). Results revealed a Foreground Bias, in which participants initially processed the foreground information at the exclusion of background information. Interestingly, this bias persisted in Experiment 2 when the initial fixation position within the scene image was modified such that even when fixating the scene background, participants continued to show a Foreground Bias. This was true for the shortest presentation duration (50ms) and dissipated once the presentation duration exceeded 100ms. In Experiment 3, we changed the task to further emphasize the scene category information (for a more global oriented task), but found that the Foreground Bias persisted. We conclude that the Foreground Bias arises from initial processing of scenes for understanding and suggests that attention is initially focused on the foreground and over time expands to include background information. Implications for scene gist perception and scene representation theories will be discussed.

62.23, 11:30 am **Scene content is predominantly conveyed by high spatial frequencies in scene-selective visual cortex** Dirk B. Walther[1](bernhardt-walther@psych.utoronto.ca), Daniel Berman[2], Julie D. Golomb[2]; [1]Department of Psychology, University of Toronto, [2]Department of Psychology, The Ohio State University

In complex real-world scenes, image content is conveyed by a large collection of intertwined visual features. The visual system disentangles these features in order to extract information about image content. Here, we investigate the role of one integral component: the content of spatial frequencies in an image. Specifically, we measure the amount of image content carried by low versus high spatial frequencies for the representation of real-world scenes in scene-selective regions of human visual cortex. To this end, we attempted to decode scene categories from the brain activity patterns of participants viewing scene images that contained the full spatial frequency spectrum, only low spatial frequencies, or only high spatial frequencies, all carefully controlled for contrast and luminance. Contrary to the findings from numerous behavioral studies and computational models that have highlighted how low spatial frequencies preferentially encode image content, decoding of scene categories from the scene-selective brain regions, including the parahippocampal place area (PPA), was significantly more accurate for high than low spatial frequency images. In fact, decoding accuracy was just as high for high spatial frequency images as for images containing the full spatial frequency spectrum in scene-selective areas PPA, RSC, OPA and object selective area LOC. We also found an interesting dissociation between the posterior and anterior subdivisions of PPA: categories were decodable from both high and low spatial frequency scenes in posterior PPA but only from high spatial frequency scenes in anterior PPA; and spatial frequency was explicitly decodable from posterior but not anterior PPA. Our results are consistent with recent findings that line drawings, which consist almost entirely of high spatial frequencies, elicit a neural representation of scene categories that is equivalent to that of full-spectrum color photographs. Collectively, these findings demonstrate the importance of high spatial frequencies for conveying the content of complex real-world scenes.

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62.24, 11:45 am **Object cues facilitate the multivariate representations of scene layout in human fMRI and MEG** Talia Brandman[1](talli.brandman@gmail.com), Marius V. Peelen[2]; [1]Center for Mind/Brain Sciences, University of Trento, [2]Donders Institute for Brain, Cognition and Behaviour, Radboud University

We recognize our surroundings even with little layout information available in the visual image, such as in fog or darkness. One way to disambiguate scenes is through object cues. For example, a boat supports the inference of a lake. Previously we have shown how scenes facilitate the neural representation of objects. The current study examines the reverse interaction, by which objects facilitate the neural representation of scene layout, using fMRI and MEG. Photographs of indoor (closed) and outdoor (open) real-world scenes were blurred such that they were difficult to categorize on their own, but easily disambiguated by the inclusion of an object. Classifiers were trained to distinguish response patterns to fully visible indoor and outdoor scenes, presented in an independent acquisition run, and then tested on layout discrimination of blurred scenes in the main experiment. fMRI results revealed a strong improvement in classification in left parahippocampal place area (PPA) and occipital place area (OPA) when objects were present, despite the reduced low-level visual feature overlap with the training set in this condition. These findings were specific to left PPA/OPA, with no evidence for object-driven facilitation in right PPA/OPA, object-selective areas, and early visual cortex. Furthermore, contextual facilitation in the left, but not right, PPA/OPA was significantly correlated with classification of objects without scenes. MEG results revealed better decoding of scenes with objects than scenes alone and objects alone, particularly at around 300 ms after stimulus onset. Altogether, these results provide evidence for inferred scene representation, which is facilitated by contextual object cues in the left scene-selective areas and at around 300 ms from visual onset. Furthermore, our findings demonstrate separate roles for left and right scene-selective cortex in scene representation, whereby left PPA/OPA represents inferred scene layout, influenced by contextual object cues, and right PPA/OPA represents a scene's visual features.

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62.25, 12:00 pm **Neural representation of object-scene scale consistency** Lauren E Welbourne[1,2](lauren.welbourne@psych.ucsb.edu), Barry Giesbrecht[1,2], Miguel P Eckstein[1,2]; [1]Psychological and Brain Sciences, University of California, Santa Barbara, [2]Institute for Collaborative Biotechnologies, University of California, Santa Barbara

To optimize finding objects in scenes the human brain guides search towards likely target locations (Torralba et al.,2006). Recent work shows that size consistency of searched objects relative to scenes ("scale consistency") contributes to search optimization (Eckstein et al.,2017), but little is known about neural representation of scale consistency. Here, we utilized fMRI to determine brain region and voxel selectivity for scale consistency. Methods: Fourteen subjects viewed 120 computer-generated images per scan (5 scans), each containing 1 of 10 objects in scenes with different scale consistency levels (from normally scaled to extremely mis-scaled). We manipulated four properties: perceived scale-consistency, real-world object size, object retinal size, and scene field-of-view. Subjects adapted to the scene (2000-3500ms) prior to object presentation (500ms). Functional ROIs (e.g. LO, PPA, TOS) were identified using localizer scans (contrast threshold p<10-5). Results: Timecourse estimates were produced for each perceived scale-consistency level using Finite Impulse Response (FIR) GLM analyses. Object region LO responded strongly to all levels, but on average showed no difference in peak beta values between normally scaled and extremely mis-scaled levels (paired t-tests, Bonferroni corrected) (t(13)=0.6186, p=NS). Conversely, significant differences were found in scene regions PPA (t(13)=11.7982, p<10-6) and TOS (t(13)=7.4838, p<10-4). MVPA, using voxel-specific HRF parameters, demonstrated high prediction accuracy for perceived scale-consistency: PPA (80%), TOS (87%), LO (87%). Cross-training with other properties, and testing on perceived scale-consistency, showed inferior but above chance decoding (<60%), suggesting an overlap of neuronal populations selective to each property. Voxel-wise encoding models also identified voxel clusters with high selectivity for perceived scale-consistency within each ROI. Conclusions: Our results suggest most voxels in PPA and TOS are selective for perceived scale-consistency, whereas LO selectivity is determined by specific voxel clusters. The MVPA cross-training and voxel-wise encoding models suggest that voxels can be jointly selective to multiple scene properties.

62.26, 12:15 pm **Interpreting Visual Representations of Neural Networks via Network Dissection** Bolei Zhou[1](bzhou@csail.mit.edu), David Bau[1], Aude Oliva[1], Antonio Torralba[1]; [1]CSAIL, MIT

The success of recent deep convolutional neural networks (CNNs) depends on learning hidden representations that can summarize the important factors of variation behind the data. However, CNNs are often criticized as being black boxes that lack interpretability, since they have millions of unexplained model parameters. In this work, we describe Network Dissection, a method that interprets networks by providing labels for the units of their deep visual representations. The proposed method quantifies the interpretability of CNN representations by evaluating the alignment between individual hidden units and a set of visual semantic concepts. By identifying the best alignments, units are given human interpretable labels across a range of objects, parts, scenes, textures, materials, and colors. The method reveals that deep representations are more transparent and interpretable than expected: we find that representations are significantly more interpretable than they would be under a random equivalently powerful basis. We apply the method to interpret and compare the latent representations of various network architectures trained to solve different supervised and self-supervised training tasks. We then examine factors affecting the network interpretability such as the number of the training iterations, regularizations, different initializations, and the network depth and width. Finally, we show that the interpreted units can be used to provide explicit explanations of a prediction given by a CNN for an image. Our results highlight that interpretability is an important property of deep neural networks that provides new insights into their hierarchical structure.

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62.27, 12:30 pm **BOLD tuning of human visual cortex to natural statistical properties in space and time** Zoey J Isherwood[1](zoey.isherwood@gmail.com), Colin WG Clifford[1], Mark M Schira[2,3], Branka Spehar[1]; [1]School of Psychology, UNSW Sydney, Sydney, Australia, [2]School of Psychology, University of Wollongong, Wollongong, [3]Neuroscience Research Australia, Sydney, Australia

Natural scenes vary considerably – forests and canyons for instance do not share obvious perceptual similarities. However, in the statistical properties of visual input that the human brain receives across natural scenes, there exists a common distribution of amplitude variations across both spatial and temporal scales. This is known as the $1/f\alpha$ amplitude spectrum, where across natural scenes $\alpha \approx 0.6 – 1.6$. Perceptual tuning to this spectral distribution has been well documented in the spatial domain using psychophysics and fMRI (Isherwood et al., 2017). It is yet to be examined, however, whether the preferential tuning of the visual system to the statistical properties of natural scenes extends to the temporal domain (i.e., the specific kind of fluctuations in visual input that tend to occur over time in natural scenes). Here, we used psychophysics and fMRI across the same subjects (N = 10) to measure perceptual sensitivity (4AFC "odd one out" task) and BOLD responses in visual areas V1-V4 to synthetic noise movies that varied in their spatial (α = 0.25, 1.25, 2.25) and temporal (α = 0.25, 0.75, 1.25, 1.75, 2.25) amplitude spectra. Just noticeable difference thresholds were smallest for natural distributions (α = 1.25)

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in both spatial and temporal domains. Thresholds were also lowest for stimuli with similar 1/f spectra in space and time, i.e. thresholds were lower for low spatial α values when temporal α values were also low. BOLD responses across visual areas and eccentricities revealed a similar pattern of results, where responses peaked for natural 1/f spatiotemporal distributions. This suggests, measured through both behaviour and physiology, that the visual system has evolved to the typical spatial and temporal properties observed in natural environments, evident by its preferential tuning toward natural scene statistics.

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Wednesday Morning Posters

Attention: Reward, motivation, emotion

Wednesday, May 23, 8:30 am - 12:30 pm, Banyan Breezeway

63.301 Reward differentially interacts with physical salience in feature-based attention Mengyuan Gong[1](gongmy@msu.edu), Taosheng Liu[1,2]; [1]Department of Psychology, Michigan State University, [2]Neuroscience Program, Michigan State University

A visual feature associated with reward can capture spatial attention when it is neither physically salient nor task relevant. Under naturalistic contexts, however, multiple sources of priority may jointly modulate the feature representation of stimuli. Much less is known about how these priorities interact to determine attentional selection. Here, we investigated the bottom-up mechanisms by which reward association interacts with physical salience (i.e., independent vs. interactive), and how top-down goals affect such interactions in a task requiring feature-based attention. We first trained subjects to associate dots moving in two coherent directions (i.e., up-left or up-right) with high and low reward, respectively. During test, we presented superimposed but perceptually separable dot stimuli that consisted of coherently moving dots and randomly moving dots. We manipulated the physical salience (low vs. high contrast) and reward-based salience (low vs. high reward) of the coherent motion in a factorial design. Subjects detected threshold-level speed-up events on either the coherent or random moving dots. We found that when the coherent motion was favored by top-down goal, high reward-associated direction received higher priority than low reward-associated direction independent of its physical salience. However, when the random motion was favored by top-down goal, high reward-associated direction was more prioritized than low reward-associated direction only when it was also physically salient. These findings suggest that reward differentially interacts with physical salience, depending on the allocation of top-down attention. Top-down attention towards the reward-associated feature allowed the priority to be independently driven by the two bottom-up sources of salience, whereas top-down attention away from the reward-associated feature counteracted the effect of reward salience, making it necessary for the physical salience to potentiate the effect of reward.

Acknowledgement: NIH R01EY022727

63.302 Feature visibility is necessary in reward-based 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

It is well established that reward biases the orienting of visual selective attention. Many studies repeatedly have shown that previously reward-signaling features involuntary capture attention even when feature-reward contingency was removed. However, little is known about the necessary components for the reward-based attentional capture. In the present study, we investigated whether reward-based capture develops even when reward-signaling features are rendered invisible via continuous flash suppression (CFS). To this end, we conducted the letter discrimination task during reward learning where the task-irrelevant colored circle signaled the magnitude of reward (i.e., high- or low-reward). During reward learning in Experiment 1, while rapidly changing Mondrian patterns stimulated the dominant eye, a reward-signaling color was presented to the nondominant eye. Moreover, in Experiment 2, stimuli were identical to Experiment 1, but reward-signaling features were provided without suppression, in which both Mondrian patterns and reward-signaling color were presented to a randomly chosen eye. After reward learning, participants completed an additional singleton task as a test phase, in which previously reward-signaling color was presented as one of the distractors, to evaluate the effect of reward-based capture. Results showed that when features were rendered invisible under CFS (Experiment 1), we could not observe the reaction times (RTs) delay in the high-reward condition, relative to the low-reward condition. However, RTs in the high-reward condition was significantly slower than that of low-reward condition when we presented features without suppression (Experiment 2). Moreover, regardless of the CFS manipulation, participants who could correctly report the reward-signaling color at a high accuracy showed attentional capture by the high-reward distractor. However, we could not obtain this reward-based capture for participants who could not discriminate reward-signaling features well. These findings suggest that visual discriminability of features associated with reward is necessary to develop reward-based attentional capture.

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63.303 Value associations combine additively with spatial cues to bias selective visual attention. Jane E Raymond[1](j.raymond@bham.ac.uk), Kelly G Garner[1]; [1]School of Psychology, University of Birmingham, UK

How does the brain's spatial attention mechanism combine predictions about where an object (target) is likely to occur with predictions about the target's reward value? Some recent human findings suggest that these different forms of prediction bias attention independently (additive-bias hypothesis) whereas others, in keeping with economic notions of expected value, point to a multiplicative operation (expected-value hypothesis). To distinguish these conflicting theoretical alternatives, we used a simple incentivised visual search paradigm involving (1) viewing two placeholders for 300-400 ms that signalled the reward value for correctly identifying any letter target appearing in that location, (2) then viewing an additional central cue for 300 ms that signalled which placeholder was more likely to get a target, and then, (3) 100 ms after cue (but not placeholder) offset, identifying a target (H, N) versus a distractor letter (Z, K) that was presented within each placeholder for 100 ms. The validity of the cue varied in blocks. As expected, we found conventional spatial cueing effects (faster correct target identification for valid versus invalid spatial cues) that scaled with cue validity. Of interest was how reward value prediction derived from the continuously present placeholders modulated these cuing effects. Across two experiments, we found strong evidence that reward value predictions boosted cueing effects additively, even when it is suboptimal to do so. These findings refute theories that an expected-value computation is the singular mechanism underlying the deployment of endogenous spatial attention. Instead, it appears that spatial certainty and value associations independently bias selective visual attention.

Acknowledgement: ESRC UK

63.304 Equating Selection History in a Value-driven Capture Paradigm: The Effects of Gains and Losses Mark W. Becker[1](-becker54@msu.edu), Eric Chantland[1], Taosheng Liu[1]; [1]Department of Psychology, Michigan State University

Rewarding attention to a particular color results in a subsequent strong capture of attention by that color. Punishing attention to a color might lead to suppression of attention to that color. Alternatively, a punished color might capture attention, if features associated with consequence capture attention, regardless of the valence of the consequence. 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 one of three possible colors. One color was associated with a modest financial gain, the other was associated with a modest financial 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. However, during the training task people correctly responded to rewarded targets more frequently than the other two target types, raising the possibility that the effects were due to selection history rather than reward contingencies. In a follow-up, during the training task an algorithm was used to dynamically alter the number of trials in each condition to ensure equal numbers of selections for each target type. Despite equating selection history during training, during test we found attention capture for the rewarded but not the punished color. Our results

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suggest that punishment does not engage the mechanism responsible for the value-driven capture effect, and these effects are not due to different selection histories.

63.305 **Reward induces the communication of task-specific visual information between the default mode and dorsal attention networks** David Rothlein[1](david.rothlein@gmail.com), Joseph DeGutis[1,2], Michael Esterman[1,3]; [1]VA Boston Healthcare System, [2]Harvard Medical School, [3]Boston University School of Medicine

When sustaining attention to a task, performance fluctuates between stable/accurate and variable/error-prone periods. Such fluctuations are, in part, modulated by motivation as reward has been shown to both boost performance and alter neural responses in brain regions critical to sustaining attention. The link between these neural changes and enhanced performance, however, is poorly understood. Thus, the present research uses fMRI and Representational Similarity Analyses to measure the influence of reward on the flow of task-relevant visual information, specifically examining the fidelity and connectivity of stimulus representations within and across brain regions critical to sustaining attention. Participants (N=16) performed the gradual onset Continuous Performance Task during an fMRI scan. This entailed viewing a series of city or mountain scenes, responding to cities (90% of trials) and withholding responses to mountains (10%). Task runs were separated into unrewarded and rewarded blocks. Representational similarity matrices (RSMs), reflecting the similarity structure of the set of city exemplars (n=10), were computed for each participant within parahippocampal place area (PPA), dorsal attention network (DAN), and default mode network (DMN) ROIs. Representational fidelity (RF) and representational connectivity (RC) were quantified as the inter-participant reliability across the RSMs from given ROI (RF) and across a pair of ROIs (RC) and were computed separately for rewarded and unrewarded blocks. We found that reward was characterized by increased RF within the DMN ($p \sim 0.05$) and increased RC between the DAN and DMN ($p < 0.01$). In striking contrast, traditional functional connectivity (time series correlations) between the DAN and DMN decreased during rewarded blocks ($p < 0.01$) suggesting that reward inhibited overall DAN-DMN communication despite facilitating the communication of task-relevant information. These results further our understanding of how motivation boosts performance during sustained attention and implicate the DMN as having an active role in the processing task-relevant visual information.

63.306 **The Impact of Performance-Based Pay and Competition on Rare Target Search Performance** Eric C. M. Chantland[1](eric-chantland@gmail.com), Mark W. Becker[1]; [1]Department of Psychology, Michigan State University, East Lansing, MI 48824, USA

When performing a visual search for rare targets, people are quick to respond target absent - indicative of a lower "quitting threshold." As a result, they often miss rare targets - the low-prevalence effect. This finding may have important implications for consequential real-world searches with rare targets (e.g., baggage and cancer screening). As a result, there have been many attempts to modify rare target search tasks to improve target detection. For the most part, these attempts have failed to increase hit rates or increases in hit rates have been accompanied by increases in false alarms– a sign of a change in decision criterion rather than sensitivity. Here we investigate whether two techniques designed to increase motivation would increase rare target search performance. In a 2 x 2 between subjects design we manipulated performance-based pay and competition with another participant. When participants competed against another participant (competing "for sport" or for monetary reward) hit rates increased (without an increase in false alarm rates) and target absent reaction times slowed (indicative of higher quitting thresholds). Performance-based pay did not improve search. In sum, having searchers compete may improve rare target search, even when the competition is simply for "bragging rights."

63.307 **Value-Driven Attentional Capture Under Threat of Shock** Andy J Kim[1](jskim628@tamu.edu), Brian A Anderson[1]; [1]Department of Psychological and Brain Sciences, College of Liberal Arts, Texas A&M University

Both reward learning and fear conditioning have been shown to influence attention to predictive cues. The extent to which these attention effects rely on common (valence-independent) or shared (valence-dependent) mechanisms is unclear. We hypothesized that, to the degree that value and threat systems influence attention via a shared mechanism, the processing of current threat should influence the attention capturing quality of reward cues. In the present study, we induced fear and anxiety through the threat of electric shock and measured resulting changes in attentional capture by reward cues. Participants first completed a training phase in which they were rewarded for fixating color-defined targets. Then, participants completed an oculomotor capture task (test phase) in which they were required to fixate a shape singleton target, while ignoring occasional distractors rendered in the high-value color from training. In an alternating block design, participants completed the test phase under the threat of electric shock and under no threat of shock. Using the State-Trait Anxiety Inventory (STAI), participants showed a significant increase in state anxiety after completion of the task, suggesting that the shock manipulation was effective in increasing anxiety. Significant oculomotor capture by the valuable distractor was observed in both threat and no-threat blocks of the task. However, no difference in capture between the two block-types was observed, and a Bayes factor analysis yielded strong support for the null hypothesis. Furthermore, there were no correlations between the difference in capture between blocks and a variety of anxiety measures assessed via questionnaires. The overall magnitude of oculomotor capture by the high-value distractor was similar to that observed in studies without a threat-of-shock manipulation. Our findings are consistent with the idea that brain systems for value and threat influence attention independently.

63.308 **Neural Mechanisms of Attentional Bias Following Aversive Conditioning** Haena Kim[1](hannah.kim@tamu.edu), Namrata Nanavaty[1], Vani A Mathur[1], Brian A Anderson[1]; [1]Department of Psychological and Brain Sciences, Texas A&M University

Stimuli previously associated with threat capture attention even when task-irrelevant and non-salient. The current study used functional magnetic resonance imaging (fMRI) to examine the neural mechanisms of attentional capture by an aversively conditioned stimulus following classical conditioning with mildly painful heat stimulation. In each trial of a training phase, either a red or a green circle was presented, one of which was followed by an aversive heat pulse on some trials (CS+). The other colour circle was never paired with a heat pulse (CS-). In a test phase, participants searched for a shape singleton. On a subset of trials, one of the distractors appeared either in the colour of the CS+ or in the colour of the CS-. Participants completed nine brain scans, including two runs of the training phase, three runs of the test phase, an anatomical scan, and then a third training run followed by two more runs of the test phase. Behavioural results revealed that response times were generally faster on CS- trials, especially during the runs immediately following training. To probe the neural correlates of distractor processing, we contrasted trials in which a CS+ distractor was present to those with a CS- distractor. The CS- distractor evoked a significantly stronger blood oxygenation level dependent (BOLD) response in regions of extrastriate visual cortex, the right inferior frontal gyrus, right temporoparietal junction, and left inferior parietal lobule. Further assessment of the trials in which a CS- distractor was present, relative to distractor absent trials, revealed a pattern of activation similar to value-driven attentional capture, suggesting that safety signals may be processed by the attention system in a similar fashion to reward cues.

63.309 **Motivational Trade-Offs Drive Attention Capture** Daniel B Dodgson[1](daniel.b.dodgson@gmail.com), Jane E Raymond[1]; [1]School of Psychology, University of Birmingham

Visual search is sometimes slowed when a previously rewarded versus unrewarded distractor is present. This so-called "value-driven attention capture" (VDAC) is widely viewed as a perceptual phenomenon; positive reward history is thought to boost a stimulus's representational strength regardless of current motivational contexts (e.g., task relevance), thus causing inappropriate attention capture (or VDAC). Alternatively, motivation could drive attention and account for VDAC via on-line computations of cost versus benefits for processing specific stimulus features. If so, then VDAC should depend on current motivational contexts, rather than on selection history alone. In this view, any concurrent secondary task, e.g., a working memory (WM) task, involving the reward-associated distractor feature should alter the cost/benefit tradeoff for this feature and consequently modulate VDAC. However, if VDAC is driven by selection history alone, then such manipulations should have no effect. To investigate, we conducted a conventional two-phase VDAC experiment, but added a concurrent visual WM task to the second, non-rewarded visual search phase in which reward-associated distractors are presented. The WM task involved maintaining either (a) colour (the reward-associated feature), or (b) shape (the target-defining feature) information during each search trial. WM tasks were matched for difficulty. We predicted that a colour WM task would increase the cost of processing the reward-associated distractor feature (colour), thus reducing motivation for processing it, and obliterating VDAC. In contrast, the shape WM task should increase shape processing costs, leaving motivation to process the distractor colour unaffected and enabling VDAC. Consistent with this motivation-driven account, VDAC was absent with a colour WM task but robust with a similarly difficult shape WM task. These effects show that selection history alone cannot account for VDAC; instead contextually determined motivational cost-benefit tradeoffs appear to drive attention and reward-association effects on processing.

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63.310 **No competition between simultaneous task cues and threat cues in visual cortex** Maeve R Boylan[1](mboylan@ufl.edu), Mia Kelly[1], Andreas Keil[1]; [1]Department of Psychology, College of Liberal Arts and Sciences, University of Florida

The visuo-cortical response to a stimulus increases when it is task-relevant, compared to task-irrelevant. Similarly, stimuli that reliably predict noxious events (threat cues) are amplified at the level of visual cortex. It is unclear how the competition between a task cue and a threat cue are resolved when they co-occur in time and in space. Utilizing electroencephalography and a Pavlovian conditioning paradigm, we investigated the visuo-cortical representation of two simultaneously presented visual stimuli by tagging the stimuli at two distinct frequencies (8.57 Hz and 12 Hz), thereby inducing two distinguishable steady-state visual evoked potentials (ssVEPs) in the visual cortex. Visual stimuli consisted of red and green random dot kinematograms (RDKs) which flickered at the tagging frequencies (e.g. red flickered at 12 Hz and green at 8.57 Hz) and exhibited random motion. Each trial began with random motion for at least 1749 ms, followed by a time range (1750-6996 ms) in which all dots in one or both RDKs could move coherently, for a duration of 1749 ms. In an initial habituation block, participants responded to coherent motion of the green RDK with a key press. Coherent motion of the red RDK in the subsequent acquisition block predicted a noxious noise, while participants still responded to green coherent motion targets. The amplitude of the ssVEPs for both red and green tagging frequencies increased from the habituation block (no loud noises) to the acquisition block, during random motion as well as during coherent motion. Across conditions, threat cue (red RDK) amplification from habituation to acquisition was not at the cost of green RDK amplitude, which also increased. Results suggest that task stimulus processing in visual cortex is not diminished when competing with a temporally circumscribed threat cue, presented at the same time and in the same position as the task cue.

Acknowledgement: NIMH

63.311 **Slimness Attracts Attention: How Body Weight Modulates Pseudoneglect** Nicole A Thomas[1](nicole.thomas@flinders.edu.au), Ellie Aniulis[1]; [1]College of Education, Psychology & Social Work, Flinders University

Within the media, we are constantly bombarded with various images, particularly in relation to advertising. Advertisements persuade us into purchasing products, regardless of need, and often images of unrealistically thin models are used to meet this goal. We developed a novel paradigm to determine whether the body weight of female models modulates visual attention (pseudoneglect). Participants (N=36 females, Mage=20.06, SD=2.60) completed a baseline version of the landmark task. In a second task, participants viewed a pair of images (one in the left visual field, one in the right) for 500ms, followed immediately by the presentation of a pre-bisected line for 500ms. Images of female models wearing swimwear or lingerie, who varied in body weight, were paired such that one model was thin and the other was overweight. We also included neutral images, which consisted of pictures of handbags that were colour matched to the model's clothing (432 trials). There was an effect of image pair, $F(6,210)=4.571$, $p < .001$, $\eta 2 = .116$. When the thin model was presented on the left, leftward biases were stronger than at baseline, and when the thin model was on the right and paired with either neutral or overweight stimuli. When the overweight model appeared on the right, leftward biases were stronger when paired with a thin model than a neutral image. Lastly, leftward biases were significantly reduced when the overweight model was presented on the left compared to all other conditions, such that pseudoneglect was no longer present ($t(35)=1.570$, $p = .126$, $d=.531$). We propose images of thin models attracted attention, while images of overweight models simultaneously repelled attention. Our findings illustrate body weight modulates pseudoneglect, providing further evidence of the concerning trend amongst young women to strive for unrealistic thinness.

Acknowledgement: Australian Research Council

Attention: Exogenous and endogenous

Wednesday, May 23, 8:30 am - 12:30 pm, Banyan Breezeway

63.313 **Endogenous Attention in Visually-Typical Children** Priyanka V Ramesh[1](pvr218@nyu.edu), Lynne Kiorpes[1]; [1]Center for Neural Science, New York University

The development of attentional skills is crucial for successfully navigating normal daily life. At any given time, we have to attend to what is most relevant to us. This type of voluntary attention, endogenous attention, is known to improve performance on a wide range of visual tasks in adults. However, relatively little is known about how and when this ability develops. In this study, we examined covert endogenous attention in visually-typical 6-10 year old children – an age range when various visual and cognitive functions are approaching maturity. The aim of the study was to assess voluntary spatial attention in children using a classic spatial cueing paradigm. Four different shapes were simultaneously presented on a touch-sensitive display screen for a brief interval (400ms) while the child maintained fixation monocularly on a central cross; the non-fixating eye was patched. Following a short delay, a response cue appeared to indicate which of the 4 locations the child must report on. The task was to select the shape that had appeared at the indicated location. Attention was manipulated by preceding stimulus presentation by a brief informative cue that accurately predicted the location of the upcoming target on half of the trials; other trials were preceded by a neutral, uninformative cue. If endogneous attention is adult-like, accuracy will be higher and response latency shorter on valid cue trials. The results showed that children as young as 6 benefit from attentional cuing: they performed significantly better on trials with a valid cue than with the neutral, uninformative cue. Response latencies were also significantly shorter for the valid cue condition. No difference was found between performance with the dominant or non-dominant eye. The results showed the typical adult pattern for covert spatial attention, suggesting that efficient deployment of voluntary attention is intact in young children.

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63.314 **Associative learning accelerates the temporal dynamics of covert exogenous spatial attention** Michael A Grubb[1](michael.grubb@trincoll.edu), Devin Butler[1]; [1]Psychology, Trinity College

Introduction: Abrupt onsets trigger the reflexive allocation of covert attention, speeding visual information processing and improving discriminability at exogenously attended locations. In the lab, neutral stimuli (e.g., small circles) are typically used to study exogenous attention. Abrupt onsets encountered in daily life, however, often carry meaning (e.g., in Gmail, onsets in the lower right visual field not only capture attention, but also signal incoming Instant Messages, thanks to a learned association). Does the behavioral signature of covert exogenous spatial attention change when elicited by meaning-imbued onsets? Methods: On each trial, covert attention was manipulated with a peripheral onset, and two Gabor patches were briefly presented at 8^{o} eccentricity (left/right of fixation). In line with a response cue, observers reported the target Gabor's orientation (clockwise/counterclockwise of vertical). Exogenous cues were valid (small circle presented near target location) or invalid (presented near distractor location); cue validity was 50%, cue-target SOA

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varied (33-133ms), and the cue was equally likely to be black or white in color. One color became meaning-imbued: following correct responses, observers were shown a randomly selected Emoji at fixation, but only when the peripheral onset had been rendered in the meaning-imbued color. Thus, observers learned to associate one type of onset (black or white peripheral circle, counterbalanced across observers) with the presentation of a novel, visually-pleasing stimulus; the other onset type provided a meaning-non-imbued baseline for each observer. A centrally-presented "X" followed all incorrect responses. Results: Both types of onsets modulated task performance (evidenced by increased accuracy and faster RTs for valid, relative to invalid, cues), but meaning-imbued onsets accelerated the timecourse: cueing effects were significantly larger at early SOAs for Emoji-predictive onsets, compared to non-predictive onsets. Conclusion: The temporal dynamics of covert exogenous spatial attention are accelerated when attentional allocation is triggered by a meaning-imbued onset.

63.315 **Endogenous and exogenous covert attention differentially modulate second-order textures** Michael Jigo[1](michael.jigo@nyu.edu), Marisa Carrasco[1,2]; [1]Center for Neural Science, New York University, [2]Department of Psychology, New York University

Introduction We use luminance-defined (first-order) and texture-defined (second-order) boundaries to segregate abutting visual patterns. The discriminability of these boundaries varies with the visual system's spatial resolution, which decreases towards the periphery. Covert exogenous spatial attention inflexibly increases spatial resolution for first- and second-order textures, resulting in improved performance at peripheral locations but impaired performance at central retinal locations. In contrast, endogenous attention flexibly adjusts resolution to improve the discriminability of first-order textures at all locations; however, it is unknown if this also occurs with second-order textures. Here, we investigated whether endogenous and exogenous attention also differentially affect second-order textures. Methods Observers performed a 2IFC texture segmentation task. We used texture stimuli composed of a first-order carrier whose luminance contrast was modulated by a Gabor (target), ensuring that the target was discriminated from the background solely by a texture-defined boundary. The target was located at 7 possible eccentricities (0°–7.2°) on the horizontal meridian. In separate sessions, we manipulated either exogenous attention with brief peripheral cues or endogenous attention with central symbolic cues that informed observers of the upcoming target location, and compared performance with a neutral condition in which an uninformative cue was presented. Results Performance (d') in the neutral condition varied non-monotonically with eccentricity, peaking in the parafovea and declining towards the fovea and periphery. Exogenous and endogenous attention yielded distinct behavioral effects. When exogenous attention was manipulated, performance was impaired in the fovea, improved in the periphery, and the performance peak shifted farther into the periphery. In contrast, endogenous attention improved performance at all eccentricities without shifting the location of the peak. Conclusion Endogenous and exogenous attention differentially modulate second-order textures. Our results provide further evidence that exogenous attention inflexibly increases spatial resolution whereas endogenous attention flexibly adjusts resolution to facilitate behavior.

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63.316 **Neural processing of task-irrelevant but salient object: an MEG study** Jianrong Jia[1,2,3,4](jiajr@pku.edu.cn), Fang Fang[1,2,3,4], Huan Luo[1,2,3]; [1]School of Psychological and Cognitive Sciences, Peking University, Beijing, China, [2]IDG/McGovern Institute for Brain Research, Peking University, Beijing, China, [3]Beijing Key Laboratory of Behavior and Mental Health, Peking University, Beijing, China, [4]Peking-Tsinghua Center for Life Sciences, Peking University, Beijing, China

In a cluttered visual environment, in addition to focusing on task-relevant objects, it is also important for attention to be occasionally captured to task-irrelevant but salient stimuli. Our previous EEG study has revealed that attention dynamically coordinates neural representations of multiple objects and flexibly modulates the sampling profile to manage different task demands (Jia et al., 2017). Meanwhile, it remains unclear how the brain deals with task-irrelevant but salient objects and further registers them into the task framework. To address the issue, we recorded magnetoencephalography (MEG) signals from 20 human subjects while they were presented with a multi-object visual display and performed a central fixation task. Notably, one of the items was made salient by being distinct from the others (e.g., red among green, etc.) but was completely task-irrelevant (i.e., demanding central fixation task). Next, we employed a temporal response function (TRF) approach (Liu et al., in press) to dissociate the time-resolved neuronal response that specifically tracks the salient (S-TRF) and non-salient (NS-TRF) items from the same MEG signals. We then performed source analysis on the S-TRF and NS-TRF responses to examine the fine spatiotemporal neuronal profiles. Our data demonstrates that salient object, compared to the non-salient one, first initiated response in right temporoparietal area (TPJ) at about 120 ms, followed by activation in left intraparietal sulcus (IPS) and bilateral frontal area, and finally reached early visual area (EVA). Interestingly, after the information was conveyed back to EVA, salient object showed higher alpha-band response compared to the non-salient one, suggesting a registration process during which the salient but task-irrelevant item was further inhibited. Our results support the crucial role of dorsal attentional network in saliency representation and provide a temporally precise and whole-brain description of how the salient information is processed, transferred, and integrated into the current task context.

63.317 **A widespread task-related hemodynamic response in human V1 is modulated by task difficulty** Minyoung Ryoo[1](Minyoung.ryoo@nih.gov), Charlie Burlingham[2], Zvi N Roth[1], David J Heeger[2,3], Elisha P Merriam[1]; [1]Laboratory of Brain and Cognition, National Institute of Mental Health, National Institutes of Health, [2]Department of Psychology, New York University, [3]Center for Neural Science, New York University

Background: The brain exhibits large-scale endogenous responses in the absence of visual stimuli at the earliest stages of visual cortical processing. There are at least two distinct types of endogenous responses: 'attention-like' responses that are spatially selective and entrained to attention cues, and 'task-related' responses that are spatially global and entrained to task timing. Purpose: Are task-related hemodynamic responses modulated by task difficulty? Method: Observers performed a two-alternative forced-choice (2AFC) orientation discrimination task, reporting whether a grating patch was tilted clockwise or counter-clockwise relative to vertical. The stimulus was a circular grating that flashed briefly in the lower right visual field. The difficulty of the task was manipulated by changing the tilt angle of the grating. In blocks of easy trials, the grating was tilted ±20° away from vertical. In blocks of difficult trials, the grating was tilted by a much smaller amount (typically ±1°), with a staircase ensuring ~70% correct discrimination accuracy. Each block had a predictable trial structure with a fixed inter-trial interval. Activity was measured in visual cortex with fMRI (3T GE scanner, 32-ch coil, multi-echo pulse sequence, 22 slices covering visual cortex, voxel size 3×3×3 mm). Results: Robust, spatially-global bilateral activity was observed during performance of the 2AFC task. Such activity was observed in all retinotopically-defined visual areas, and in non-retinotopic portions of parietal and temporal cortex. Activity in contralateral regions likely reflected a mixture of stimulus-evoked and task-related activity. Activity in early visual areas, ipsilateral to the visual stimulus, was attributed to the task-related response. This task-related activity ipsilateral to the stimulus was significantly larger during blocks of difficult trials. Conclusions: Endogenous, task-related fMRI activity is spatially extensive in the human brain. It is dissociable from activity related to sensory stimuli, and is modulated by task demands, such as the level of difficulty.

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63.318 **Involuntary orienting to visual and auditory stimuli elicits similar biasing mechanisms in early visual cortex to facilitate target processing** Viola S Störmer[1](vstoermer@ucsd.edu), John J McDonald[2], Steven A Hillyard[3]; [1]Department of Psychology, University of California, San Diego, [2]Department of Psychology, Simon Fraser University, [3]Department of Neurosciences, University of California, San Diego

A sudden visual or acoustic change in the environment can capture attention involuntarily and facilitate perceptual processing of a subsequent visual target at the same location. The behavioral consequences of this uni- and cross-modal cueing of attention have been well documented, but the underlying neural mechanisms and how they may differ depending on the modality of the cue remain elusive. Here we use EEG to directly compare the effects of visual and auditory cues on subsequent target processing and examine neural activity elicited by the cues themselves. Participants were presented with two Gabor patches at the same time (one to the left and one to the right of fixation) and were asked to indicate the orientation of the Gabor that appeared higher in contrast (cf., Carrasco et al., 2004). Prior to the presentation of these visual targets a non-predictive visual (Exp.1) or auditory (Exp.2) cue was presented at either the left or right location. Across both experiments we found that participants judged the Gabor patch on the cued side to have higher contrast (visual: $t(19)=3.76$, $p=0.001$; auditory: $t(15)=4.07$, $p< 0.001$), consistent with previous findings. Furthermore, in both cases, these behavioral effects were accompanied by a boost in early cortical processing beginning at 100ms post target onset (visual: $p=0.00001$; auditory: $p=0.004$) On trials where no targets were presented, visual and auditory cues elicited a slow positive deflection over contralateral visual cortex between 260 to 360ms post cue onset (visual: $p< 0.0001$; auditory: $p< 0.0002$). The time course of this cue-elicited neural biasing over visual areas matches the well-established time course of the behavioral benefits of exogenous cueing of attention. Overall, these results indicate that sudden events in the environment – regardless of sensory modality – cause reflexive shifts of attention that result in similar neural modulations in visual cortex.

63.319 **A Rational Analysis Account of Voluntary Symbolic Attention Control** Joseph R. Pauszek[1](jpauszek@nd.edu), Bradley S. Gibson[1]; [1]University of Notre Dame

Abundant evidence in the attention literature has been interpreted to suggest that humans routinely use symbolic spatial cues like arrows or directional words to guide visual attention in everyday life. However, this literature has not considered the wide range of factors that influence voluntary choice behavior. Drawing from the rapidly growing decision making literature, we propose a rational analysis account of voluntary symbolic attention control – the Least Costs Hypothesis (LCH) – which construes voluntary control as a decision between intentional cue use and unguided search. In this view, observers deliberately pursue the strategy associated with fewer anticipated costs. The present study employed a spatial cuing paradigm and inferred voluntary cue use by the magnitude of "unbiased costs-plus-benefits," with larger magnitude effects reflecting greater cue usage. Consistent with the LCH, observers' decision was found to be sensitive to variations in cue processing efficiency. In Experiment 1, observers demonstrated a robust preference for using "easy-to-process" arrow cues to satisfy an easy visual search goal, relative to "hard-to-process" spatial word cues. Experiment 2 showed that this preference persisted even when the temporal costs of cue processing were neutralized (Figures 1 and 2). In Experiment 3, observers reported this cue type preference outside the context of a speeded task, and Experiment 4 showed empirical measures of this bias to be relatively stable over the duration of the experiment (Figure 3). Together with other evidence suggesting that observers' decision between intentional cue use and unguided search is also influenced by practice with the task and variations in unguided search efficiency, these findings suggest that voluntary symbolic attention control is mediated by ongoing metacognitive evaluations of demand that are sensitive to perceived variations in the time, effort, and opportunity costs of each strategy. Thus, voluntary symbolic attention control is far more complex than previously held.

63.320 **Metacognitive judgments and perceptual decisions rely on different information.** Kyuin Kim[1](polarbearjj1a@gmail.com), Sang Chul Chong[1,2]; [1]Graduate Program in Cognitive Science, Yonsei University, [2]Department of Psychology, Yonsei University

Recent studies suggest that metacognitive judgments (type-2) rely on information that is not accessible to a perceptual decision-making process (type-1). To explore what kind of information type-2 tasks rely on, we asked participants to perform both type-1 and type-2 tasks while manipulating bottom-up attention; They decided whether the right edge of a target was above or below the horizontal meridian (type-1 task) and simultaneously judged their confidence in the decision (type-2 task). The stimuli were oriented bars (25˚-65˚ either clockwise or counter-clockwise from the horizontal meridian) presented to the left and right visual fields in a rectangular (Exp. 1) or circular (Exp. 2) grid. Among them, a randomly selected bar was cued as the target. Before the stimuli appeared, a rectangular (Exp. 1) or arc-shaped (Exp. 2) frame was briefly flashed in either of visual fields to draw attention. Type-1 sensitivity, type-2 sensitivity, and the ratio between them (metacognitive efficiency) were calculated both when the target was attended and unattended. Metacognitive efficiency signifies how much of the information used in the type-1 task is available to the type-2 task. We found that type-1 sensitivity was higher in the attended condition, but metacognitive efficiency was similar (Exp. 1) or even lower (Exp. 2). Furthermore, confidence ratings were higher in the attended condition regardless of the correctness of the perceptual decision. Metacognition might have reflected whether attention was allocated to the target, which would increase the subjective sense that one is correct. Further analysis of the target orientation confirmed this idea. Participants were more confident about targets with a larger orientation difference from the horizontal meridian, while their type-1 performance was similar. These results suggest that metacognition on perceptual discrimination exploits proxy evidence that influences a subjective sense of correctness, which is independent from the perceptual decision itself.

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Perception and Action: Affordances and judgments

Wednesday, May 23, 8:30 am - 12:30 pm, Banyan Breezeway

63.321 **Tool identity and subsequent use affects the kinematics of grasping movements** Diana Tonin[1](D.tonin@uea.ac.uk), Ralph Pawling[2], Katrina Leyden[1], Fraser W Smith[1], Stephanie Rossit[1]; [1]School of Psychology, University of East Anglia, Norwich, UK, [2]School of Natural Sciences & Psychology, Liverpool John Moores University, Liverpool, UK

Tools are manipulable objects that, unlike other objects in the world (e.g., buildings), afford specific action procedures closely linked to object identity. Several studies have shown that differences between structural (e.g., spoon handle size, shape and orientation) and learned functional (e.g., stir, poor or feed) properties of tools can translate to distinct motor affordances. Most studies to date however have used pictures instead of real tools and measured reaction times rather than hand movement kinematics. To investigate how tool identity and subsequent use affect grasping kinematics 18 participants performed two grasping tasks with their right-hand: 1) grasp-to-use (GTU), where participants grasped a tool to demonstrate its typical use; and 2) grasp-to-move (GTM) where participants grasped a tool to move it from one location to another. Critically, participants grasped real 3D familiar kitchen tools with the same handle, so that any kinematic effects could not be simply due to the structural differences between tool handles. Moreover, to control for differences between GTU and GTM kinematics we only analysed the first portion of the movement (i.e., grasping the handle), as this was identical between tasks and tools. We found that participants presented larger grip apertures for the GTU than the GTM tasks, which may reflect differences in the kinematics of subsequent actions following the handle grasp. Moreover, for both tasks participants presented larger grip apertures for tools that had larger tool heads (e.g., whisk) compared to tools with smaller tool heads (e.g., knife), even though the tool handle that was grasped was of identical size across tools. These results indicate that tool identity plays a critical role in action planning and execution.

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63.322 **Luminance and surface texture discontinuities affect perception of object reachability in virtual reality.** Jonathan K Doyon[1](jonathan.doyon@usm.edu), Joseph D Clark[1], Tyler Surber[1], Alen Hajnal[1]; [1]Department of Psychology, University of Southern Mississippi

We investigated the effects of surface texture discontinuities and surface luminance on the perception of an object's reachability. Fifty-four naïve subjects were tested in an affordance paradigm where participants provided judgments about the reachability of a small graspable virtual object (a ping-pong ball) in several virtual scenes using the Oculus Rift

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virtual reality headset. Participants viewed objects at distances defined as intrinsic ratios of object distance to arm-length. Seven pi-ratios ranging from 0.7 to 1.3 were used during testing, such that anything less than or equal to 1.0 was considered reachable and anything greater than 1.0 was considered not reachable. In Experiment 1, stimuli were randomized across four tabletop conditions in which we varied both surface luminance and the presence of a surface texture discontinuity. Luminance varied as the ratio of white-to-black surface texture; high luminance tabletops were all white or mostly white, low luminance tabletops were all black or mostly black. When present, the discontinuity occurred 50cm from the participant where the edges of the two textures met. In Experiment 2, stimuli were randomized across five tabletop conditions in which both the presence and location of the discontinuity were varied, along with luminance. The discontinuity occurred at 25%, 50%, and 75% of the table's length away from the participant. We found significant interactions between discontinuity and pi and between luminance and pi. These effects indicate that subjects were more likely to respond "no" to the reachability question both when a discontinuity was present as pi-ratios increased, and under high luminance conditions as pi-ratios increased. Light (i.e., the information for vision) and surface texture gradients carry consequences for the realization of reaching affordances both in the real world and in virtual environments.

63.323 **Learning intermediate features of affordances with a convolutional neural network** Aria Y Wang[1](yuanw3@andrew.cmu.edu), Michael J Tarr[1,2]; [1]Center for the Neural Basis of Cognition (CNBC), Carnegie Mellon University , [2]Psychology Department, Carnegie Mellon University

The ability of humans to interact with the world around us relies on our ability to infer what actions objects afford - often referred to as affordances. The neural mechanisms of object-action associations are realized in the visuomotor pathway where information about both visual properties and actions is integrated into common representations. However, explicating these mechanisms is particularly challenging in the case of affordances because there is no one-to-one mapping between visual features and inferred actions. To better understand the nature of affordances, we trained a deep Convolutional Neural Network (CNN) to predict affordances from images and to learn the underlying features or the dimensionality of affordances. We view this representational analysis as the first step towards a more formal account of how humans perceive and interact with the environment. To create an affordance dataset, we labeled each of over 500 object categories with up to 5 actions drawn from a pool of 56 action categories. Since each action label was object-based (e.g., "kick" for a ball and "drink" for water), these labels can be generalized as "image to affordance" mappings for large-scale image datasets such as ImageNet (Russakovsky, 2015). Using these datasets we then trained a CNN (VGG-19; Simonyan 2014) to predict affordances for images in ImageNet. Using a network with pre-trained weights we were able to predict affordances with an accuracy of 87%. In contrast, a network trained from scratch achieved an accuracy of 24% (where chance is 5%). To quantify the interpretability of hidden units at intermediate layers within both networks, we applied network dissection (Bau, 2017) to identify the features critical for classifying affordances. Such features form an underlying compositional structure for the general representation of affordances which can then be tested against human neural data.

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63.324 **Affording Both: Do the Same Underlying Mechanisms Account for Action-specific and Affordance Perception?** mike tymoski[1](tymoski@rams.colostate.edu), Jessica Witt[2]; [1]Colorado State University, [2]Colorado State University

Some researchers speculate that action-specific effects, like the distance on hill (DoH) effect – where individuals perceive distances on hills as farther than equal distances on flat ground, due to an increased energetic cost to walk those distances – are simply spatial judgments grounded in perceived affordances, or environmentally supported opportunities to act. Essentially, the claim is that action-specific effects are misinterpreted evidence for affordance perception. If action-specific effects were simply affordance judgments converted to spatial estimates, participants who were more accurate at judging affordances would also be more likely to show a larger DoH effect. To test this prediction, we measured the magnitude of the DoH effect and compared it with accuracy on an affordance task. Previously, the affordance task was to estimate passability of doorways of various widths. We found no correlation between performance on the two, r= -0.036, p=0.753; which we then replicated, r= -.0891, p=0.441. However, the affordance task related to body size, whereas the DoH effect is a function of energetic demands. Thus, in a new study, we developed and used a novel energetics-based affordance task. In VR, participants judged whether they would be able to run through a dynamic aperture that was placed 10 meters up a 30 degree hill and that closed at 1 of 8 speeds. Just noticeable difference (JND) scores were calculated to determine each participant's sensitivity to change in afforded passability as a function of closing speed. Once again we found a significant DoH effect, t(42)= 3.17, p=0.003, and good reliability and variability in performance for both tasks, but no correlation between performance on the two tasks, r=-0.066, p=0.669. These results, in conjunction with our previous findings, suggest that action-specific and affordance perception are distinct phenomena, and rely on different mechanisms.

63.325 **Distancces Appear Farther on Hills: Evidence for Top-Down Effects** Emily L Laitin[1](emily.laitin@colostate.edu), Michael J Tymoski[1], Nathan L Tenhunfeld[1], Jessica K Witt[1]; [1]Department of Psychology, College of Natural Sciences, Colorado State University

The action-specific account of perception states that a perceiver's ability to act influences the perception of the environment. For example, participants tend to perceive distances as farther when on hills than on flat planes (Stefanucci et al., 2005). This is known as the Distance-on-Hill (DoH) Effect. However, critics of the action-specific account of perception claim that such effects could be due to participants guessing the hypothesis and trying to comply with the experimental demands. The present studies explored the DoH effect to explore whether it is truly perceptual or due to response bias. Participants judged the distance to targets on a hill and on the flat ground in a virtual reality environment. They stood between the hill and a flat surface and saw a cone on each surface. They manipulated one of the cones with the goal of making both cones equidistant. For half the trials, participants manipulated the cone on the hill; for the other half, they manipulated the cone on the flat surface. First, we replicated the DoH effect that the distances on the hill appeared farther (p < .005). In a second study, we provided feedback on their responses ("Too far" or "Too close"). Despite this feedback, participants still judged cones on hills to be farther than on flat surfaces[T1] (p < .001). We also applied the El Greco fallacy: if the effects were truly perceptual, when judging cones on two hills against each other, the effects should cancel each other out, but if the effects were due to response bias, the effect of the hill should still emerge. As predicted, participants moved the cones similarly when both cones were on the hill and when both cones were on the flat surface (p=.72). This also furthers the evidence towards the DoH effect being perceptual.

63.326 **Action-Specific Perception Depends on Relative Performance when Judging Speed via a Speed-Bisection Task and Absolute Performance when Judging Speed via a Magnitude Estimation Task** Jessica K Witt[1](jessica.witt@colostate.edu); [1]Department of Psychology, College of Natural Sciences, Colorado State University

Spatial perception is influenced by the perceiver's ability to perform an action. For example, when playing a modified version of the classic computer game Pong, participants see the ball as moving faster when they play with a small paddle than when they play with a big paddle. The small paddle is less effective at blocking the ball, and this is theorized to be the reason why the ball looks faster. A critical question concerns the mechanism by which action exerts its influence on perception. The mechanism must have two components: a source of information about the action and a process by which the source exerts its influence. In the current experiments, I explored whether the source of information is a function of relative information about performance, or absolute performance. Specifically, does the medium paddle, which leads to approximately 80% of balls successfully blocked, produce similar effects on perceived ball speed regardless of context, or does it matter if the medium paddle is paired with the big paddle (95% balls blocked) versus the small paddle (45% balls

blocked)? In other words, the medium paddle is a more effective paddle in the context of the small paddle but a less effective paddle in the context of the big paddle. Does this context matter for action's influence on perception? In the first study, participants estimated ball speed by performing a speed bisection task for which they classified each ball as moving more like the slow speed or more like the fast speed. The data clearly show that relative, rather than absolute, performance influences perceived speed. In the second study, participants estimated ball speed by rating the speed of the ball on a scale of 1-7. The data clearly show that absolute, rather than relative, performance influences perceived ball speed. Thus, a mystery ensues.

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63.327 **Failure is Not an Option: Testing the Effects of Automation Failure on the Perceptual System** Nicholas J Fitzgerald[1](Nick.Fitzgerald.Noco@gmail.com), Nathan L Tenhundfeld[1], Jessica K Witt[1]; [1]Department of Psychology, College of Natural Sciences, Colorado State University

Tools that enhance performance also influence spatial perception, such as a stick making an object appear closer if the individual wielding said stick has the intention to reach with it. Does this same principle apply to automated processes that also improve performance? Participants attempted to block a ball using a small paddle, and then estimated the speed of the ball. We improved ball-blocking performance using two separate manipulations. The first manipulation was a larger paddle that the participant controlled; the second manipulation was automating the small paddle. Across the five experiments we found that the ball appeared slower to participants when using the larger paddle compared to the small paddle. This replicated the Pong effect and shows that tools influence spatial perception. Interestingly, when the small paddle was automated, perceived speed was not influenced by the paddle's ball blocking performance. The ball appeared the same speed regardless of whether the automated paddle was programmed to successfully block the ball 50% or 95% of the time. This suggests that automated processes are not embodied in the same way as tools. When the tool improved performance (i.e. the big paddle) perceived ball speed was affected. When automation improved performance, perceived ball speed was unaffected. The automated paddle also did not influence speed perception when it was engaged for the whole trial and when it failed 30% of the time, in which case the participant had to take control of the paddle. Automated processes are not like sticks, with respect to embodied perception. Only when the participant is acting does performance influence perception. This is evidence that perception is action-specific.

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63.328 **Identifying blurry scenes with translational optic flow, rotational optic flow or combined optic flow** Jing Samantha Pan[1](panj27@mail.sysu.edu.cn), Hongyuan Wu[1]; [1]Department of Psychology, Sun Yat-sen University

When observers move, optic flow, which is generated by motion, and image structure, which is projected from world surfaces, become available. Optic flow specifies spatial relations and calibrates image structure; calibrated image structure preserves spatial relations specified by optic flow after motion stops. Interacting optic flow and image structure enable stationary blurry-vision observers to perceive events when they view objects in motion (Pan et al, 2017). Similarly, when a blurry–vision observer locomotes, optic flow and blurry image structure should allow her to perceive surrounding stationary scenes. Furthermore, a locomoting observer simultaneously experiences translational optic flow generated by locomotion and rotational optic flow generated by eye movement. Because translational flow specifies depth layout and rotational flow does not, blurry scenes should be perceptible with translational flow but not with rotational flow. However, when both flows are present, is the resultant flow compromised in its power to specify spatial layout because rotational flow serves as noise to the system; or is the resultant flow as powerful as translational flow in specifying spatial layout because the flows work in a winner-take-all fashion? We studied these questions in three experiments, where participants identified scenes from blurry static images and from blurry videos, which contained translational flow (Experiment 1), rotational flow (Experiment 2) or both (Experiment 3). When first viewing blurry images, participants did not identify the scenes. When viewing blurry videos, scenes were perceived with translational flow, but were not with rotational flow. Scenes were equally accurately perceived when both flows existed, suggesting that the two flows work in a winner-take-all fashion. One week after viewing the blurry videos, participants successfully perceived scenes from the static blurry images. Therefore, regardless of rotational flow, as long as translational flow is available, it interacts with blurry image structure to yield accurate and stable scene perception.

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63.329 **Similarities and differences in the representation of real objects and images: insights from inverse multidimensional scaling** Desiree E Holler[1](DesireeHoller@gmail.com), Sara Fabbri[1], Jacqueline C Snow[1]; [1]The University of Nevada, Reno

Two-dimensional (2-D) images of objects are commonly used as proxies to access the organization of conceptual knowledge in the brain. However, various studies from our lab highlight differences between images and real objects at the neural level (Snow et al, 2011), as well as in their contribution to memory (Snow et al., 2014), attention (Gomez et al., in press), and decision-making (Romero et al., in press). Asking an observer to judge the similarities among a set of objects can provide unique insights into the underlying neural representations in human cortex (Mur et al, 2013). Here, we used inverse multidimensional scaling (Kriegeskorte and Mur 2012) to investigate the properties that observers use to characterize objects displayed as 2-D images versus real objects. Observers arranged 21 different items so that the distances between them reflect their perceived dissimilarities. Half of the participants (n=68) arranged 2-D images on a computer monitor; the other half arranged the corresponding real-world exemplars manually on a table top. Critically, participants were not given a criterion to sort the objects, but were free to use any dimension they liked to group the items. By correlating models based on the various sorting criteria with the dissimilarity matrix obtained by the behavioral ratings, we identified the properties that observers used to separate the items within each format. Stepwise linear regression showed that both common and different criteria were used to arrange images and real objects. For example, for both formats, the location where the item is typically encountered was a salient dimension, as was elongation. However, unlike 2-D images, real objects were also sorted based on properties relevant for their manipulation, specifically, their physical size and weight. These results suggest that despite their similarly with respect to the semantic properties, 2-D images lack the representational richness of their real-world counterparts.

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63.330 **Attenuated tilt illusion for real-world displays versus pictorial displays** Michael A Gomez[1](michaelgomez@unr.edu), Michael A Webster[1], Jacqueline C Snow[1]; [1]Psychology, College of Liberal Arts, University of Nevada, Reno

The cognitive processes that mediate visual perception are dissociable from those of visually-guided action. For example, pictorial illusions bias perceptual judgments, but not the calibration of manual grasps. We wondered whether pictorial illusions elicit perceptual biases similar to those of real-world three-dimensional stimuli (that afford, but do not require, manual interaction). To address this question, we conducted a psychophysical experiment to measure the effect of display format on the tilt illusion. In the tilt illusion, the perceived orientation of a central test grating is altered by the presence of a simultaneously presented surround grating with a different orientation. On each trial, observers adjusted the orientation of a central test grating so that it appeared to be vertical in orientation. The surround gratings were oriented 12○ to the left or right of vertical. Critically, in 'real' blocks, participants performed their perceptual judgments on a tilt illusion stimulus comprised of solid white wooden rectangular prisms mounted against a black background; the orientation of the test grating was varied around the vertical axis using a computer-controlled servomotor. In 'image' blocks, participants performed their perceptual judgments on high-resolution two-dimensional computerized images of the real-world display. The images were matched closely to their real-world counterparts for pictorial depth cues, illumination, size

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and distance. We found that although the tilt illusion was present in both stimulus formats, the magnitude of the illusion was markedly reduced for the real-world displays.

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63.331 **With this tilt, I dub you cute: Head tilt increases cuteness in puppies and adult dogs** Muna Amry[1](muna_amry@mymail.eku.edu), Catrina H White[2], Derek K. McClellan[3], D. Alexander Varakin[4]; [1]Department of Psychology, Eastern Kentucky University

Cuteness is a physical attribute of human infants and other animal species that often induces a caring response in adults. Past research on cuteness has focused on physical features of the face and body. The purpose of the current studies is to test whether behavioral features can affect cuteness. The behavior we focused on was head tilt. In Experiment 1, participants (N = 86) viewed a puppy picture on each trial, and controlled the degree of head tilt. In one block, participants were instructed to make the puppy as cute as possible, and in another block to make the puppies' heads vertical. The average head-tilt angle for cute-instructions (M = 13.65 degrees) was significantly further from 0 degrees than the average upright-instructions angle (M = 5.32 degrees), p < .05. A second experiment was a survey that asked participants (N = 236) to rate pictures (1-7) from least cute to most cute. It featured the puppy pictures and pictures of adult dogs displaying vertical heads or tilted heads. Pictures of puppies (M = 5.77) were rated as cuter than pictures of adult dogs (M = 4.40), but head tilt did not have a significant effect for either age group. In a third experiment, participants again controlled head tilt, but the adult dog pictures used in Experiment 2 were used in addition to the puppy pictures. Replicating Experiment 1, the average cute-instruction angle (M= 13.31) was significantly further from 0 degrees than the vertical- instruction angle (M= 4.90), p< .05, and the effect was present in for pictures of puppies and adult dogs. These results suggest that head tilt, when controllable, can increase cuteness of animals that are already very cute (puppies) and those that are less cute (adult dogs).

Eye Movements: Perception and remapping

Wednesday, May 23, 8:30 am - 12:30 pm, Banyan Breezeway

63.332 **Evoked responses to transient stimuli are associated with saccade reaction time** Jonathan O Touryan[1], David Slayback[1], Anthony J Ries[1]; [1]Human Research and Engineering Directorate, U.S. Army Research Laboratory

Eye movements are a pervasive element of our everyday interactions with the environment and can be systematically planned (voluntary) or in response to the abrupt onset of a stimulus (reactive). While voluntary and reactive saccades have been linked to different cortical pathways, many questions remain about their constituent networks. In this study we sought to identify the neural activity associated with reactive saccades by using synchronized EEG and eye tracking measures. Here, participants conducted a free-viewing visual search over a distribution of static Gabor stimuli in order to identify, via button press, the vertically oriented targets. During the search, transient Gabor stimuli were also presented, requiring an immediate saccade in order to assess orientation before stimulus extinction. In our analysis, we separated these reactive saccades into quartiles based on the time between stimulus presentation and saccade onset (i.e. saccade reaction time, SRT). The corresponding stimulus and saccade-locked event-related potentials were then estimated using both standard averaging and regression-based techniques. We found that the amplitude of the late positive potential, evoked by transient stimuli, exhibited a significant inverse relationship with SRT. This phenomenon persisted even when accounting for the effects of Gabor spatial frequency, saccade magnitude, and EEG activity related to ocular muscle artifacts. Our results suggest that the late positive potential, commonly associated with attentional capture, may also index the onset of reactive saccades.

63.333 **Detecting motion-changes with peripheral vision: On the superiority of fixating over tracking.** Christian Vater[1](christian.vater@ispw.unibe.ch), Andre Klostermann[1], Ernst-Joachim Hossner[1]; [1]University of Bern, Institute of Sport Science

Peripheral-motion-change-detection performance was examined by contrasting a fixation with a SPEM condition. To that end, participants were confronted with a visual display consisting of 15 white squares and 1 red square circulating with 6°/s (tracking condition) and stopping in-between (fixation condition). The instruction was to visually follow the red square and to press a button as soon as a white square begins to move. The to-be-detected white square movements varied in eccentricity and speed. A Vicon-integrated eye-tracking system was used for controlling gaze behaviour. Response times (ms) and missed detections (%) were measured as dependent variables. Results in Experiment 1 show faster motion-change detection in fixation vs. tracking condition (401 ms vs. 809 ms) and increased response times as a function of eccentricity in the tracking condition only (4°: 570 ms; 8°: 737 ms; 16°: 1121 ms). Moreover, missed detections were revealed at 16° eccentricity in the tracking condition only. Experiment 2 controlled for foveal load as possible confounder by replacing the red square with a virtual centre evoked by 4 red squares. The same results were obtained as in Experiment 1. In Experiment 3 we tested motion-detections with fixations and SPEM at 9 eccentricities (4-20°). We observed constant response times for fixations over the eccentricities (around 550ms), but during SPEM, response times increased from 4° (701 ms) to 14° (895 ms) to 20° (1433 ms). Missed detections were again only observed at eccentricities of 16° and higher. In sum, it could be shown that SPEM impair the ability to detect peripheral motion changes.

63.334 **Perceptual enhancements during microsaccade preparation** Natalya D Shelchkova[1](nshelch@gmail.com), Michele Rucci[2,4], Martina Poletti[3,4]; [1]Department of Psychological and Brain Sciences, College of Arts and Sciences, Boston University, [2]Department of Neuroscience, University of Rochester, [3]Department of Brain & Cognitive Sciences, University of Rochester, [4]The Center for Visual Science, University of Rochester

It is known that a tight relationship exists between saccades and attention, and that processing of saccade targets starts well before an eye movement is initiated. Does this bond extend to the scale of the foveola, the small high-resolution region of the retina? This region only covers approximately 1 degree of visual angle but is disproportionately important for human vision. Here we investigate whether microsaccade preparation leads to selective perceptual enhancement at the microsaccade target location within the foveola. While observers (n=6) fixated on a marker, a central saccade cue appeared. Observers were instructed to shift their gaze, via a microsaccade, toward a location 20′ away in the direction indicated by the saccade cue. Before a microsaccade was performed, two probes (7′x2′ bars) were flashed, one at the cued location and the other at the opposite side. A response cue indicated one of the two locations after the execution of the microsaccade, and observers reported the orientation of the bar previously presented at that position. Performance was assessed separately in the congruent trials in which the microsaccade landed at the response cue location and in the incongruent trials where microsaccades landed at the opposite location. Performance was also tested in neutral trials without saccade cue. Discrimination was enhanced in the congruent trials compared to incongruent and neutral trials (d′: 1.8, 1.3, 0.8, in congruent, neutral and incongruent trials, respectively; ANOVA F(2,5) = 19, p=0.0004). This result was not the outcome of a voluntary shift in covert attention; performance was similar in congruent and incongruent trials when observers maintained fixation (d′: 1.4 vs. 1.3, p=0.8; t-test). Our findings show that fine spatial vision is enhanced prior to the execution of microsaccades. This enhancement occurs selectively at the future landing position of the microsaccade, while performance at other nearby locations is impaired.

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63.335 **Mapping visibility around the blind spot** Annegret Meermeier[1,2](a_meer05@uni-muenster.de), Markus Lappe[1,2], Michele Rucci[3,4]; [1]Department of Psychology, University of Muenster, [2]Otto Creutzfeld Center, University of Muenster, [3]Department of Brain & Cognitive Sciences, University of Rochester , [4]The Center for Visual Science, University of Rochester

The natural blind spot, the retinal scotoma at ~15° eccentricity, is a necessary nuisance for the visual system, as it corresponds to the location where nerve fibers and blood vessels go through the retina. Although the anatomy of the blind spot is well characterized, little is known about visual functions at the edges of the blind spot and how signals in this region affect perceptual filling in within the blind spot itself. A funda-

mental challenge to this end is the incessant presence of eye movements in the human eye, which, in standard experimental procedures, smear visibility maps around the blind spot. To circumvent these problems, here we combined several experimental techniques and mapped the blind spot borders of the human right eye along the horizontal meridian. The eye movements of 5 observers were recorded at high-resolution using a newly developed digital Dual Purkinje eye-tracker, a system with sub-arcminute resolution. A specially-designed calibration procedure enabled accurate positioning of a visual probe (a 2x2 arcmin high-contrast dot displayed for 14 ms) relative to the line of sight. The probe was maintained at a fixed location on the retina by means of retinal stabilization, a procedure that continually updates the position of the stimulus on the monitor to compensate for the observer's eye movements. In a 2AFC task, subjects reported detection of the probe via button press. We determined the detection rate as a function of visual eccentricity. We show that the transition zone from full visibility to total invisibility around the blind spot covers approximately 30′. On average, at the nasal side, visibility dropped from 75% to 25% in approximately 11′. At the temporal side visibility increased from 25% to 75% in approximately 17′. These results show the existence of intermediate visibility zones surrounding the blind spot.

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63.336 **Eye Movements as Indicators of Scene Grammar Inconsistencies** Do Hyong Koh[1](dohyong.koh001@umb.edu), Akram Bayat[1], Anubhkaw Kunar Nand[1], Marc Pomplun[1], Shaohua Jia[1]; [1]Computer Science Department, University of Massachusetts Boston

Saliency models are able to predict the locations of gaze fixations in free-viewing tasks at an above-chance level, meaning that subjects tend to fixate on higher saliency objects sooner and more often. However, these models are based on low-level features, and thus their predictive power diminishes for certain viewing tasks and scenes that involve high-level cognition. High-level features such as scene semantics can cause discrepancies between the predicted saliency map and the recorded eye movements in the scene. Furthermore, it is known that attentional capture by high-level, semantic information tends to go along with increases in fixation duration and pupil size variance. An interesting question then is: To what extent can these behavioral variables predict the influence of high-level factors on the distribution of visual attention, as indicated by the difference between saliency and fixation maps? As a starting point, we considered the effect of objects which violate the scene grammar. Such objects are inconsistent with the embedding scene, such as a printer in a kitchen, or with the laws of physics, such as a plate floating in the air. Subjects viewed a total of 128 scenes, and their task was to indicate whether each scene contained an inconsistency, which was the case in 64 of them. We measured and analyzed the subjects' eye movements and changes in pupil size during this task. Our initial data analysis showed that subjects were indeed likely to fixate on the violating objects early in the task and with longer fixation duration. In terms of pupillary responses, subjects revealed high variance around the time when they recognized the scene grammar violation. A preliminary evaluation of these data indicated that these two variables might indeed be robust indicators of high-level scene features, at least in the present scene-grammar based task.

63.337 **Fixation stability during global motion discrimination tasks** Kimberly Meier[1](kmeier@psych.ubc.ca), Deborah Giaschi[2], Miriam Spering[2]; [1]Department of Psychology, University of British Columbia, [2]Department of Ophthalmology & Visual Sciences, University of British Columbia

Introduction: Beyond the characteristic deficit in visual acuity in one eye, people with unilateral amblyopia (lazy eye) show deficits on a range of visual functions including motion perception at slow speeds. These deficits are usually attributed to the abnormal development of low-level visual motion processing mechanisms. However, unstable fixation has been reported in amblyopia, and may impact motion perception by degrading the input received by direction-selective neurons. Here we ask whether poor performance on slow motion tasks can be accounted for by poor fixation stability. To establish this relation in control observers, we assessed fixation stability in adults with healthy vision during a motion perception task. Methods: Participants (n = 24) performed a global motion direction discrimination task (left/right) with stimuli (600 ms duration) moving at a slow (1 deg/s) or fast (32 deg/s) speed. Dot coherence was controlled with a staircase procedure to obtain coherence thresholds. In a control condition, participants viewed stationary dot patterns. Participants were asked to fixate a central cross throughout the task. Eye movements were recorded with an Eyelink 1000+. Bivariate contour ellipse area and the number of microsaccades on each trial were calculated as indices of stability. Results: Fixation was more stable for the motion discrimination task at either speed, compared to stationary viewing. Participants' overall stability did not predict their coherence thresholds on the motion discrimination task for either speed. Conclusions: Healthy adults show no clear relationship between eye movement stability and global motion coherence thresholds. This suggests fixation instability may not solely account for the motion perception deficits observed in amblyopia.

Acknowledgement: Natural Sciences and Engineering Research Council of Canada

63.338 **Binocular coordination when focussing on bright and dark objects** Anke Huckauf[1](anke.huckauf@uni-ulm.de); [1]General Psychology, Ulm University, Germany

Looking at a rouged face gives the impression of more depth of that face. This is thought to be an effect of increased brightness differences between dark and bright parts. Here, the question arises whether such differences affect already basic visual functions like, for example, binocular coordination. Evidence for this assumption can be found in reading literature. Here, there is mixed evidence published on a seemingly different question, namely whether typical binocular coordination during reading results in more crossed (as observed by Nuthmann & Kliegl, 2009) or more uncrossed (e.g., Liversedge, White, Findlay, and Rayner, 2006) fixations. Interestingly, between these studies texts differed in brightness. In three experiments, we investigated the question of whether brightness differences of the text lead to a preponderance of crossed or uncrossed fixations. Binocular coordination was measured via SMI IViewX eye tracker. In Experiment 1, the eyes were calibrated using Gabor patches presented on grey background. When using the same grey background during measurement, there was no change in fixation disparity. However, replicating both earlier findings, reading dark on bright background resulted in more crossed, and reading bright on dark background in more uncrossed fixations. These effects were replicated in Experiment 2 using a bright as well as a dark background for calibration. They were also replicated in Experiment 3 when reading from paper. The data strongly indicate that brightness changes alter binocular coordination. Whereas unsystematic increases of variance might relate to inaccuracies of eye tracking, the replicability of systematic differences in mean vergence across experiments showed that binocular coordination differs for bright and dark objects. This can neither be regarded as an artefact of calibration nor of using a self-illuminating screen. One might further assume that vergence can serve as a measure for distance estimation at near sight.

Acknowledgement: German Resrach Foundation (DFG) collaborative research centre Companion Technologies

63.339 **Learning to see through the saccadic veil** Yuval Porat[1,2](y-porat@gmail.com), Ehud Zohary[1,2]; [1]The Edmond and Lily Safra Center for Brain Sciences, The Hebrew University of Jerusalem, Jerusalem 91904, Israel , [2]Department of Neurobiology, The Alexander Silberman Institute of Life Sciences, The Hebrew University of Jerusalem, Jerusalem 91904, Israel

Introduction: Visual sensitivity is markedly reduced during an eye movement. Peri-saccadic vision is also characterized by a mislocalization of the briefly presented stimulus closer to the saccadic target. These features are commonly viewed as obligatory elements of peri-saccadic vision. However, practice improves performance in many perceptual tasks performed at threshold conditions. In the current research we asked if this could also be the case with peri-saccadic perception. Methods & Results: To test this, we used a paradigm in which subjects reported the orientation (or location) of a horizontal or vertical ellipse briefly presented during a saccade. The aspect ratio of the ellipse' main axes was varied across trials. Thus some trials were extremely difficult (aspect ratio close to 1) while others were relatively easy (aspect ratio: 1>1). Practice on peri-saccadic orientation discrimination led to long-lasting gains in that task (i.e. a larger slope of the psychometric curve) but did not alter the classical mislocalization of the visual stimulus. Shape discrimination gains were largely generalized to other untrained conditions when the same stimuli

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were used (discrimination during a saccade in the opposite direction or at a different stimulus location than previously trained). However, performance dropped to baseline level when participants shifted to a novel Vernier discrimination task under identical saccade conditions. Furthermore, practice on the location task did not induce better stimulus localization or discrimination. Conclusions: These results suggest that the limited visual information available during a saccade may be better used with practice, possibly by focusing attention on the specific target features or a better readout of the available information. Saccadic mislocalization, by contrast, is robust and resistant to top-down modulations, suggesting that it involves an automatic process triggered by the upcoming execution of a saccade (e.g., an efference copy signal).

63.340 **Distractor displacements during saccades are reflected in the time-course of saccade curvature** Artem V Belopolsky[1](A. Belopolsky@psy.vu.nl), Jonathan van Leeuwen[1]; [1]Vrije Universiteit Amsterdam

Every time we make a saccade we form a prediction about where objects are going to be when the eye lands. This is crucial since the oculomotor system is retinotopically organized and every saccade drastically changes the projection of objects on the retina. We investigated how quickly the oculomotor system accommodates new spatial information when a distractor is displaced during a saccade. Participants performed sequences of horizontal and vertical saccades and oculomotor competition was induced by presenting a task-irrelevant distractor before the first saccade. On half of the trials the distractor remained in the same location after the first saccade and on the other half the distractor moved during the first saccade. Curvature of the second saccade was used to track target-distractor competition. At short intersaccadic intervals, saccades curved away from the original distractor location, confirming that in the oculomotor system spatiotopic representations emerge rapidly and automatically. Approximately 190 ms after the first saccade, second saccades curved away from the new distractor location. These results show that after a saccade the oculomotor system is initially driven by the spatial prediction made before the saccade, but it is able to quickly update these spatial predictions based on new visual information.

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63.341 **From retinal to world-centered perception of intra-saccadic motion streaks: Evidence for high-fidelity eye position information during saccades** Richard Schweitzer[1,2,3](richard. schweitzer@hu-berlin.de), Tamara Watson[4], Tarryn Balsdon[5], Martin Rolfs[1,2]; [1]Bernstein Center for Computational Neuroscience Berlin, Germany, [2]Department of Psychology, Humboldt-Universität zu Berlin, Germany, [3]Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Germany, [4]School of Social Sciences and Psychology, Western Sydney University, Australia, [5]School of Psychology, University of New South Wales, Sydney, Australia

With each saccade, visual objects cause motion streaks across the retina in the direction opposite of the movement. In the absence of pre- and post-saccadic stimulation, these intra-saccadic motion streaks are often visible. The investigation of their phenomenology provides the opportunity to assess how the visual system integrates retinal and eye position information to achieve world-centered perception as the eyes move. Participants (N=10) made horizontal saccades (16 degree of visual angle, dva), as we used a high-speed projection system (1440 frames per second) to present rapid, continuous, intra-saccadic stimulus motion: Starting at one of nine different locations on the screen, a low spatial frequency noise patch moved in one of 12 possible directions, traveling 3, 4.5, or 6 dva at a velocity of 240 dva/s. After each saccade, participants reported whether they had perceived a motion streak during the movement, and if so, reproduced its path on the screen using a computer mouse. Motion streaks were detected in 71% of all trials. Detection improved with lower retinal velocities and when the noise stimulus (on a given trial) happened to contain orientation information parallel to its retinal trajectory, thereby producing more pronounced streaks. Localizations in space were also best explained by the stimulus' retinal rather than world-centered position. In contrast, the perceived trajectory of motion—including its direction, length, and overall path—was more similar to the stimulus' world-centered path. Moreover, motion streaks that extended further in time and space were more likely to be reported in world-centered coordinates. Thus, while intra-saccadic perception emanates from processing in retinal coordinates, it is readily available in world-centered coordinates, suggesting the visual system has access to a high-fidelity representation about the position of the eyes even during saccades. Our results also provide evidence that motion streaks might well play a role in trans-saccadic vision.

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63.342 **Does the visual system's perceptual stabilization of small eye movements affect visual performance?** Adela SY Park[1](apark@student.unimelb.edu.au), Andrew B Metha[1], Phillip A Bedggood[1], Andrew J Anderson[1]; [1]Department of Optometry & Vision Sciences, The University of Melbourne

Even when we stare intently at an object, our eyes constantly make small, involuntary eye movements. However, the incessant motion of the retina that arises goes unnoticed due to perceptual stabilization mechanisms. It remains largely unexplored whether these mechanisms have consequence for visual performance. Observers can group a grid of regularly arranged elements into rows or columns when alternate rows (or columns) are presented with an imperceptible temporal offset, allowing small eye movements to subtly shift the position of the alternate rows or columns (Wallis 2006). We incorporated this temporal row/column grouping task within a visual illusion, which temporarily disables perceptual stabilization mechanisms through a 10Hz flickering annulus of random noise (Murakami 2003). We presented alternate grid elements over two successive display frames, with either no stimulus displayed at other times (brief presentation) or a complete (i.e. alternate elements presented simultaneously) grid displayed both before and after (extended presentation). Observers' ability to correctly group the grid stimulus in accordance with alternate row or column presentations were measured in the presence and absence of perceptual stability (i.e. non-flickering vs flickering annulus) for both grid presentation conditions. For brief presentations, flicker had no measurable effect on temporal row/column grouping (n=12; grouping performance (median): flickering 58.6% vs. non-flickering 58.0%; Wilcoxon signed-rank test, p=0.700). For extended presentations, grouping performance was significantly different between flickering and non-flickering surrounds (flickering 58.6% vs. non-flickering 52.2%; p=0.025). Our findings suggest that perceptual stabilization of small eye movements can have a small, but measurable effect on temporal row/column grouping. Murakami, I. (2003). "Illusory jitter in a static stimulus surrounded by a synchronously flickering pattern." Vision Res 43(9): 957-969. Wallis, G. (2006). "The temporal and spatial limits of compensation for fixational eye movements." Vision Res 46(18): 2848-2858.

63.343 **Localizing visual targets across saccades: Do nontarget landmarks really help?** Xiaoli Zhang[1](zhang.4734@osu.edu), Julie D Golomb[1]; [1]Department of Psychology, The Ohio State University

The image on our retina changes every time we make an eye movement; therefore, it is important to understand how we maintain visual stability across saccades. Specifically, to locate visual targets, we may use nontarget objects as "landmarks". In the current study, we compared how the presence of nontargets (NTs) affects target localization across saccades and during sustained fixation. Participants fixated at a target object, which either maintained its location on the screen (sustained-fixation trials), or displaced to trigger a saccade (saccade trials). After the target disappeared, participants reported the most recent target location with a mouse click. We varied the reference frame in which NTs appeared across saccades: the same locations relative to the target ("Relative"), the same locations relative to the display screen ("Absolute"), or not until the saccade target was presented ("Baseline"). First, we found that the presence of NTs decreased both response error and variability. Interestingly, this NT facilitation effect was the same magnitude for saccade trials and sustained-fixation trials, indicating that NT facilitation might be a general effect on target localization, not specific to saccadic stability. Second, participants' responses were biased towards the NT locations, i.e., the location of spatial references. Both the NT facilitation and NT bias effects were weaker in the Absolute condition compared to the other two conditions, suggesting that the relative spatial relationship between the target and NTs is particularly influential for target localization. Additionally, the initial fixation location and actual saccade landing position also biased target location reports, suggesting that eye movement paths may also be stored as spatial references, and may interact with NTs to influence spatial localization. In summary, the presence of NTs facilitates target localization instead of saccadic stability per se, but it also biases responses, showing that although there is facilitation, it may not be optimal.

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63.344 A blanking effect for trans-saccadic colour changes

Carolin Hübner[1](carolin.huebner@uni-marburg.de), Alexander C. Schütz[1]; [1]AG Allgemeine und Biologische Psychologie, Philipps-Universität Marburg

Human vision faces the challenge of producing a stable representation of the world given large distortions induced by eye movements. Alongside retinal displacement of a visual target goes a lack of sensitivity during saccades. Thus, it might not be surprising that trans-saccadic displacements of visual targets have been shown to go largely unnoticed. However, blanking the target for a few 100 milliseconds after a saccade facilitates the change detection for spatial features such as location or spatial frequency (Deubel, Schneider, & Bridgeman, 1996; Poth, Herwig, & Schneider, 2015). We investigated if this effect holds for non-spatial features, and if the potential increase in performance due to blanking can be predicted by pre- and post-saccadic discriminability separately. In the first experiment, we tested colour discrimination providing relevant visual input only in the periphery before a saccade or only in the fovea after a saccade. Participants had to judge whether the hue of a target stimulus was more red or blue than the average of all stimuli presented beforehand. Post-saccadic target presentation followed saccade initiation either directly or after a 200-ms blank. Based on pre- and post-saccadic discriminability we predicted the discrimination of trans-saccadic changes with or without blanking, as tested in the second experiment: Here, the coloured stimuli appeared both pre- and post-saccadically but changed their hue during the saccade to different degrees. Participants had to judge the difference between the pre- and post-saccadic stimulus. Again, a 200-ms blank could precede the post-saccadic stimulus or not. We found better change discrimination with blanking but this could not be predicted given the pre- and post-saccadic discriminability with and without blanking. In conclusion, the blanking effect might result from a modulation of the perceived common cause of the two visual inputs as suggested previously rather than from a modulation of feature discriminability.

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63.345 Transsaccadic integration is unaffected by saccade landing point

Stefan Van der Stigchel[1](s.vanderstigchel@uu.nl), Nathan Van der Stoep[1], Martijn Schut[1]; [1]Experimental Psychology, Helmholtz Institute, Utrecht University

The experience of our visual surroundings appears continuous, contradicting the erratic nature of visual processing due to saccades. The visual system constructs a continuous experience by integrating pre-saccadic and post-saccadic visual input. Because saccades rarely land exactly at the intended location, transsaccadic integration would need to be robust against variations in actual saccade execution. In the current study participants reported a feature (here color) of the saccade target, which occasionally changed slightly during the saccade. In transsaccadic change-trials, participants reported a mixture of the pre- and post-saccadic color, indicating transsaccadic integration. Importantly, saccade landing distance was not a significant predictor for the color reported. In a second experiment, we used a global effect paradigm in which a distractor appeared together with the saccade target, causing most saccades to land in between the saccade target and distractor. Again, there was no effect of saccade landing point on the outcome of transsaccadic integration. Surprisingly, this even holds for saccades landing close to the distractor, remote from the target. Therefore, transsaccadic perception is robust against deviations in saccade landing point even when saccades land outside of the range of everyday oculomotor variance. Transsaccadic integration therefore depends on the intended saccade location, not on the actual landing position of the eye.

63.346 Transsacadic Integration of Multiple Objects and The Influence of Stable Allocentric Cue

George Tomou[1,2,3](gtomou@yorku.ca), Xiaogang Yan[1,2], J. Douglas Crawford[1,2,3,4,5]; [1]Centre for Vision Research, York University, [2]Vision: Science to Applications (VISTA), York University, [3]Department of Psychology, York University, [4]Department of Biology, York University, [5]Department of Kinesiology, York University

Transsaccadic integration is the ability to retain and synthesize visual information between different stable fixations. In order to do this, the brain must be able to retain and update object locations and features despite relative changes in retinal location produced by saccades several times per second. It is known that humans are able to retain several objects across saccades based on egocentric mechanisms, but it is not known what role allocentric landmarks play in this process. In order to test this, we compared performance in a transsaccadic integration task (e.g., Prime et al. Exp. Brain Res. 2007) with or without the presence of an allocentric landmark. 1-7 Gabor patches with pseudorandom orientations were presented on a frontal screen while participants fixated a randomized fixation cross. Following a visual mask, participants were required to saccade to a new location and were asked to identify whether a new Gabor patch presented at one of the same locations was rotated clockwise or counterclockwise from the original orientation. In 50% of the trials, an allocentric landmark (a stable cross positioned pseudorandomly within the stimulus array and extending across the screen) was presented throughout the trial. Using generalized linear mixed modeling (GLMM), results from 9 participants confirmed the expected result that in the absence of the landmark, performance decreased significantly (from a baseline of ~90% correct) as the set size increased ($p < .001$). More importantly, the presence of the landmark ameliorated this decrease in performance, providing significantly better performance for set sizes of 3 and higher ($p = .029$). These preliminary results suggest that egocentric and allocentric mechanisms may combine to provide optimal performance in transsaccadic integration of multiple objects.

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63.347 Trans-saccadic feature integration relies on luminance contrast

Lukasz Grzeczkowski[1](lukasz.grzeczkowski@gmail.com.com), Martin Szinte[2], Heiner Deubel[1]; [1]Allgemeine und Experimentelle Psychologie, Department Psychologie, Ludwig-Maximilians-Universität München, Munich, Germany., [2]Department of Experimental and Applied Psychology, Vrije Universiteit, Amsterdam, Netherlands

Across eye movements, the visual system receives two successive images of the pre- and the post-saccadic retinal projections of the visual field. The existence of a mechanism integrating these images across saccades is still nowadays a matter of debate. One way to study trans-saccadic information transfer and integration is to use a blanking paradigm. Indeed, while a small trans-saccadic object displacement normally stays unnoticed, blanking the object after the saccade makes the same displacement easily noticeable. Recently, it was shown that this blanking effect is reduced when the trans-saccadic object is isoluminant relative to the background. Using the blanking paradigm, we here study the effect of luminance and isoluminance on the transfer of a visual feature across saccades. Observers performed an eye movement to a peripheral Gabor grating and discriminated an orientation change that occurred across the saccade. Pre- and post-saccadic gratings were either isoluminant or contained luminance contrast. The post-saccadic Gabor was either presented with or without a 200 ms blank. With non-isoluminant objects we observed an improvement of discrimination with a blank, i.e., a blanking effect for an orientation change across the saccade. Interestingly however, discrimination did not benefit from the blanking if the pre-saccadic grating was isoluminant. The results demonstrate that not just displacement detection, but also the trans-saccadic integration of visual features can benefit from post-saccadic blanking. Moreover, trans-saccadic feature integration turns out to be dependent on luminance contrast. We propose that these effects reflect the existence of a trans-saccadic feature integration mechanism that relies largely on luminance contrast.

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63.348 **Optimal integration of retinal and extra-retinal information is contingent upon trans-saccadic discontinuity**
Avi M Aizenman[1](avigael_aizenman@berkeley.edu), Dennis M Levi [1], Preeti Verghese[2], Sevda Agaoglu[1]; [1]University of California, Berkeley, [2]The Smith-Kettlewell Eye Research Institute

During saccadic eye movements visual sensitivity decreases due to saccadic suppression1, which degrades spatial information of the target location. This implies that the visual system does not have precise information of target location during saccades. However, previous work showed that sensitivity to displacement during saccades is improved by blanking the target prior to displacement2. These results are consistent with the idea that the visual system assumes that the environment is stable unless there is "sufficient" evidence to the contrary. Alternatively, the visual system could be using both retinal and extra-retinal information in an optimal way3. If this is true, perceptual stability, measured as sensitivity to displacement, should correlate with oculomotor stability such that reduced saccadic accuracy and precision should lead to poor perceptual performance. In Experiment 1, each trial began with a fixation target. After 1-1.5s, the target jumped either to the right or left by 8 degrees. This jump served as a "go" signal for the observer to make an eye movement to this peripheral target. Contingent upon saccade onset, the target was then displaced with various amounts right or left. On 'blank' trials, the target disappeared after saccade initiation for 200msec. Observers reported the direction of target displacement. In Experiment 2, we measured fixation stability while observers viewed an empty screen or a fixation target on an otherwise blank screen. Psychometric functions were fit to observers' displacement direction responses. We computed correlations between the bias and slope parameters of the psychometric functions and oculomotor metrics such as fixation stability, saccade accuracy, and saccade precision. We found a significant correlation between the slope of psychometric functions and both signed saccade accuracy and precision, only in the 'blank' condition. This suggests that retinal and extra-retinal information can be used optimally if there is sufficient evidence to overcome the stability assumption.

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63.349 **Localization errors following saccadic adaptation to a dichoptic step**
Anna A Kosovicheva[1](anna.kosov@gmail.com), Oishi Hawlader[2], Peter J Bex[1]; [1]Department of Psychology, Northeastern University, [2]Gonzaga High School

In saccadic adaptation, saccade amplitudes change to account for errors in saccade landing location. Saccadic adaptation also produces mislocalizations around the adapted target location (Bahcall & Kowler, 1999; Awater, Burr, Lappe, Morrone, Goldberg, 2005). While saccadic adaptation is typically tested with identical target steps in each eye, previous work has demonstrated that the oculomotor system can adaptively recalibrate saccade amplitudes in response to opposite target shifts in each eye (Maiello, Harrison, & Bex, 2016). We investigate the perceptual effects of adaptation to a dichoptic step: are localization errors consistent with changes in saccade amplitude in different directions in the two eyes? Subjects made repeated rightward saccades to a Gabor target at 8º eccentricity, and shutter glasses were used to introduce a dichoptic step. On saccade onset, the saccade target stepped 0.8º inward in the left eye and 0.8º outward in the right eye, remaining onscreen following saccade completion. After 75 adaptation trials, subjects were shown probe trials (interleaved with top-up adaptation trials) to measure perceptual shifts following adaptation. During probe trials, subjects performed a post-saccadic Vernier discrimination task with a pair of brief (100 ms) lines, each shown to a different eye. Following adaptation, in order to appear collinear, each Vernier line needed to be shifted in the same direction as the adapting step in the corresponding eye. The perceived misalignment was significantly larger compared to a control condition in which subjects adapted to identical inward steps in both eyes (mean total misalignment of -0.44º vs. -0.03º; $p = 0.008$). Similar mislocalizations were observed when comparing the apparent locations of pre- and post- saccadic probes, indicating that each line was shifted relative to the pre-saccadic goal. Together, these results are consistent with previously reported mislocalizations following conjugate target steps, and demonstrate novel dichoptic visual errors following oculomotor adaptation.

Visual Memory: Change detection

Wednesday, May 23, 8:30 am - 12:30 pm, Pavilion

63.401 **Pay attention to this, not that: Feature repetition prevents task-irrelevant feature processing**
Katherine C Moen[1](kmoen1@lsu.edu), Sunghyun Kim[1], Rebecca R Goldstein[1], Melissa R Beck[1]; [1]Psychology, Louisiana State University

Research suggests that visual working memory (VWM) storage is object based because participants automatically encode task-irrelevant features (Yin et al., 2012). However, the degree to which task-irrelevant features are encoded may vary depending on stimuli properties and the strength of the attention set for the task-relevant feature. For example, task-irrelevant features may not be stored when individuals are able to group stimuli by task-relevant features (van Lamsweerde & Beck, 2015). The current study examined if task-irrelevant features are automatically stored when participants have a strong attention set for task-relevant features, and when participants are able to group stimuli based on task-relevant feature similarity. Participants completed a change detection task with four colored shapes. In order to encourage a strong attentional set for color, participants were instructed to only detect color changes, and only color changes occurred during the first block of trials. Participants then completed a second block, with a seamless transition between the blocks, where either (1) color (task-relevant), (2) shape (task-irrelevant), or (3) both color and shape changes could occur. In order to encourage stimuli grouping based on the task relevant feature (color), feature repetition occurred on half of the trials (two different shapes shared the same color). For no repetition trials (replication of Yin et al., 2012), four unique shapes, each with a unique color, were presented. Accuracy did not differ between task-irrelevant and no change trials, suggesting that participants were not processing the task-irrelevant feature. Additionally, accuracy was higher for repetition trials than for no repetition trials, but only for task-relevant changes. These results suggest that, task-irrelevant features are not processed automatically when participants have a strong attention set for task-relevant features and when it is possible to group stimuli in VWM by similar features.

63.402 **The role of memory retrieval and decision when dividing attention in a Gabor patch change detection task**
James C Moreland[1](jamesm37@uw.edu), John Palmer[1], Geoffrey M Boynton[1]; [1]Department of Psychology, University of Washington

The change detection paradigm has been used to implicate perception, memory and decision in effects of divided attention for simple features such as orientation or contrast (e.g. Mayo & Maunsell, 2016; Pestilli, Carrasco, Heeger, & Gardner, 2011; Scott-Brown & Orbach, 1998). We ask whether the effects of divided attention are due to perceptual limits, memory encoding or storage, memory retrieval and/or decision. We use three tasks – simple change detection, post-cued change detection and retro-cued change detection – using the same stimuli and procedure to determine the source of the limits in change detection. Subjects were presented with two intervals of dynamic 1/f noise patches on the left and right sides of fixation and were pre-cued to attend to either one side (cue-one) or both sides (cue-both). For the simple change detection task, Gabors were embedded in the noise on both sides, in both intervals, with a 50% chance of a change occurring between intervals somewhere. For the post-cued change detection task, stimuli were the same (including cue-one and cue-both conditions) but now the chance of change was 50% independent on each side with a post-to indicate the relevant side. For the retro-cued change detection task, stimuli were the same but an additional cue was added between the intervals matching the post-cue. For the simple change detection task, subjects performed worse in the cue-both condition compared to cue-one. This effect was reduced but still reliable for the post-cued change detection task. However, for the retro-cued task where only one memory retrieval, comparison and decision must be made, there was no difference between the cue-one and cue-both conditions. Results are consistent with divided attention effects in this change detection task being due to the processing of memory retrieval, comparison and decision. They are inconsistent with accounts based on perception, memory encoding and storage.

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63.403 **Storage unit in visual working memory depends on the visual information load of a memory display** Jiehui Qian[1](jiehui.qian@gmail.com), Shengxi Lei[1], Ke Zhang[1], Quan Lei[2]; [1]Department of Psychology, Sun Yat-Sen University, [2]Department of Psychology, University of Minnesota

Visual working memory (VWM) is a cognitive memory buffer for temporarily processing and storing visual information. Previous studies suggest that its capacity is severely limited, and there is an ongoing debate on whether the capacity is fixed or flexible depending on the complexity of the items retained in the VWM. In the present study, a change detection task was employed to investigate whether and how the visual information load can affect VWM, specifically, its capacity and the unit of storage. Information load was manipulated through the set size and the complexity of memory items. We tested two types of stimuli: the single-feature type where each item in the memory array was composed of a single feature (color/shape), and the conjunctive-feature type where each item was composed of a conjunction of two features (color & shape). We varied perceptual complexity by using different types of feature and the demanded resolution of representation. Experiment 1 replicated the previous findings that the memory capacity for color is larger than shape, and capacity in VWM decreased as the resolution demand increased (i.e., changes were more subtle to detect) regardless of the type of feature tested. In Experiment 2, we analyzed and compared the results from single-feature objects and conjunctive-feature objects in the low- and high- resolution conditions while controlling for the number of to-be-remembered features. By directly matching the estimated capacity based on object-unit and feature-unit with the theoretical prediction, the results showed that the unit of storage in VWM tended to be feature-based if visual information load was low, and to be object-based if information load was high. This suggests that visual working memory is dynamic and flexible, dependent on the load of the current task.

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63.404 **The capacity of visual working memory for scenes** Kazuhiko Yokosawa[1](yokosawa@l.u-tokyo.ac.jp), Qi Li[1]; [1]The University of Tokyo

How many scenes can we encode and maintain in visual working memory (VWM)? Previous research suggests that VWM stores three to four objects at a time, independently of the number of features possessed by each object (Luck & Vogel, 1997; Vogel, Woodman, & Luck, 2001). In the present study, we examined VWM capacity for scenes using a change detection task. In Experiment 1, the memory array consisted of 1-8 images of scenes and was presented for 300ms. After a 1700-ms retention interval, a test array consisting of one image was presented. This image was either an old image, presented at the same position as in the memory array, or it was a new image, presented at one of the positions in the memory array. The number of scenes maintained in VWM was estimated using Cowan's K formula (K = (hit rate − correct rejection rate) × set size, Cowan, 2001). Results revealed that VWM performance reached a stable plateau around two scenes. In Experiment 2, the duration of the memory array was extended to 600ms to test whether the length of encoding time affects the capacity of VWM for scenes. We found that the pattern of results was almost identical to that observed in Experiment 1. In Experiment 3, the retention interval was shortened to 700ms to test whether the capacity for scenes can be enlarged. However, the results still showed a similar capacity limit of about two scenes. Our three experiments consistently show that VWM can encode and maintain only about two scenes at a time.

63.405 **The Effects of Change Probability and Object Typicality on Visual Working Memory and Visual Attention** Eduardo E Hernandez[1](ehern11@lsu.edu), Katherine C Moen[1], Melissa R Beck[1]; [1]Psychology, Louisiana State University

Change detection performance is better for probable changes than for improbable changes (Beck, Angelone, & Levin, 2004). For example, a lamp turning from on to off (probable change) is noticed more often than a floor lamp changing into a table lamp (improbable change). Additionally, change detection performance is better for objects that are inconsistent with scene (atypical objects), than changes to objects that are consistent with the scene (typical objects, Hollingworth & Henderson, 2003). The current study sought to replicate these effects and to test for possible interacting effects of object typicality and change probability on visual working memory and visual attention. All participants saw each study scene for two seconds, a blank screen for one second, and then the test scene until the participant clicked on the object that changed. Each study scene contained four objects that could change: (1) a typical object with a probable change, (2) a typical object with an improbable change, (3) an atypical object with a probable change, or (4) an atypical object with an improbable change. Change probability and typicality effects were replicated: Probable changes were detected more often than improbable changes and changes to atypical objects were detected more often than changes to typical objects. Additionally, there was an interaction between change probability and object typicality: The effect of change probability was much stronger for typical objects than for atypical objects. Specifically, improbable changes to typical objects were missed more often than any other type of change. Eye-movement data demonstrated that these effects were due to how attention was being allocated. While viewing the study scene, typical objects with an improbable change were fixated less frequently and attention dwelled on them for less time than the of the other three types of objects.

63.407 **Apple of my eye: Incidental learning of change probability biases visual attention to food categories** Anna M Wright[1](awrigh4@gmail.com), Katherine C Moen[1], Melissa R Beck[1]; [1]Psychology, Louisiana State University

Participants can learn to bias attention towards items in a scene that have a high probability of change (Beck et al., 2017). The current study investigated this effect using categories of stimuli that have shared features. We used unprocessed and processed foods because processed foods tend to have angular edges, whereas unprocessed foods tend to be curvilinear. Participants detected identity changes in arrays of three processed and three unprocessed foods. In the control condition, processed and unprocessed foods changed equally often. In the unprocessed probable condition, unprocessed foods changed on 80% of the trials, and in the processed probable condition, processed foods changed on 80% of the trials. In both the control condition and processed probable conditions, change detection performance was higher for processed foods than for unprocessed foods. However, in the unprocessed probable condition, change detection performance was equal for the two food types. Eye tracking data demonstrated that this was due to an attentional bias for processed foods that was overcome when unprocessed foods were more likely to change. In both the control and the processed probable conditions, the first stimulus participants fixated was more often a processed item as opposed to an unprocessed item, and more time overall was spent fixating processed items. In the unprocessed probable condition, first fixations were equally likely to fall on processed and unprocessed items, and total time spent fixating was the same for both food types. These data show that existing attention biases toward a category in which the stimuli share features (e.g., processed foods) can be modified by making another category with a different shared feature more task relevant.

Visual Memory: Long term memory

Wednesday, May 23, 8:30 am - 12:30 pm, Pavilion

63.409 **Up-regulatory nature of voluntary control for visual long-term memory encoding and its down-regulatory side effects** Caitlin Tozios[1](caitlin.tozios@mail.utoronto.ca), Keisuke Fukuda[1]; [1]University of Toronto

The capacity for visual long-term memory (VLTM) to store detailed and accurate representations of images is quite remarkable (e.g., Brady et al., 2008). However, the nature and the extent of voluntary control over the quality of VLTM encoding is unclear. To test this, we sequentially presented a pair of random objects for participants to remember. Critically in some trials, one of the paired objects was cued to be up-regulated (i.e., try harder to remember) or to be down-regulated (i.e., try not to remember) either before (Experiment 1; pre-cue) or after (Experiment 2; post-cue) the onset of the objects. Here we found that participants successfully up-regulated the quality of memory encoding regardless of the cue-to-object stimulus onset asynchrony (SOA). However, they failed to down-regulate the quality of memory encoding regardless of cue-to-object SOA. Interestingly, we also observed reliable down-regulation of memory encoding quality for objects that accompanied up-regulated objects, only when the cue was provided prior to the onset of the objects. To further

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investigate the underlying neural mechanisms of voluntary control of memory encoding, we repeated the pre-cue experiment while measuring participants' electroencephalograms (EEG). Our results showed that participants reduced the posterior alpha (8-14Hz) power contralateral to the up-regulation cue following the cue onset, thus reflecting the exertion of selective attention to the to-be-up-regulated object. Taken together, these results suggest that our ability to voluntarily control the memory encoding quality is up-regulatory in nature, but it can be used to indirectly down-regulate the memory encoding quality of accompanying stimuli only if the cue is provided before the stimuli onset in order to attentionaly bias the perceptual encoding of the stimulus.

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63.410 **The intrinsic memorability of an image is associated with familiarity and recollection** Nico Broers[1,2](nicobroers1988@gmail.com), Niko A. Busch[1,2]; [1]University of Muenster, [2]Otto-Creutzfeld Center for Cognitive and Behavioral Neuroscience, Muenster

Images contain the feature of memorability: across a wide range of contexts and observers, the same pictures tend to be remembered or tend to be forgotten. Most previous studies have investigated memorability using recognition tests, which require a decision as to whether a given image is old or new. In principle, recognition can be based on a vague feeling of familiarity ("I feel like I have seen something like this before.") or on recollection of specific image details ("I remember seeing the house with the green door."). It is currently unknown whether memorable images are more recognizable due to an increased sense of familiarity or due to recollection of more detailed memories. Here, we used Receiver Operating Characteristics (ROCs) to disentangle the contribution of familiarity and recollection to memorability. In a study phase, participants (n = 50, mean age = 29, 31 female) were presented with a stream of images for 500 ms each, and classified each image as indoor/outdoor. In the following test phase, old target items were intermixed with new lure items. Participants decided whether an image was old or new and indicated their confidence on a scale from 1 ("Sure") to 3 ("Not Sure"). Both target and lure images covered the full range from very memorable to very forgettable, as determined by previous studies using these images. As expected, images found to be memorable in previous studies also tended to be more recognizable in our study, as indicated by a larger area under the ROC curves. We fitted a Dual Process Signal Detection Model to our ROC data and found that both familiarity and recollection parameters were significantly increased for memorable images. Thus, memorable images are recognized better due to stronger feelings of familiarity, but also due to recollection of specific image details.

63.411 **Visual memorability in the absence of semantic content** Qi Lin[1](qi.lin@yale.edu), Sami R Yousif[1], Brian Scholl[1], Marvin M Chun[1,2,3]; [1]Department of Psychology, Yale University, [2]Interdepartmental Neuroscience Program, Yale School of Medicine, [3]Department of Neuroscience, Yale School of Medicine

What makes an image memorable? Recent work has characterized an intrinsic property of images, memorability, which predicts the likelihood of an image being remembered across observers (Isola et al.,2011; Bainbridge et al.,2013). Memorable images frequently contained objects and humans — raising the question of whether there is memorability in the absence of semantic content. Here, we describe visual memorability: memorability that is driven not by semantic content but by low-level visual features per se. Participants viewed a sequence of natural scene images (sampled from Isola et al.,2014) and made a response whenever they saw an image that they had seen previously during the task. Replicating previous findings, memorability was reliable across individuals, and these memorability scores were significantly correlated with those from the original study. To eliminate semantic content, we then transformed the original natural scene images using transformations such as phase-scrambling or texture-scrambling, and tested their memorability using the same paradigm in independent samples. Unsurprisingly, transformed images were significantly less memorable than the original meaningful images. Critically, however, we still found reliable memorability for both types of scrambling. That is, certain images were more likely to be remembered across observers, even when they contained little-to-no semantic content. Interestingly, memorability scores for intact, phase-scrambled, and texture-scrambled images were unrelated: an image that was memorable once transformed was not necessarily memorable in the original sample, and vice versa. Furthermore, when we used a computer vision model previously trained to predict memorability (Khosla et al.,2015), the predictions for the scrambled images did not predict the memorability of the scrambled images themselves — although they did predict the memorability of the original images, suggesting that scrambling preserves low-level features that predict memorability. Thus, our results expand prior work and suggest that there is pure visual memorability that operates independently of semantic content.

63.412 **Incidental versus intentional image memorability** Lore Goetschalckx[1](lore.goetschalckx@kuleuven.be), Jade Moors[1], Johan Wagemans[1]; [1]Laboratory of Experimental Psychology, KU Leuven

Recent studies using repeat-detection memory tasks have shown that images differ consistently in their memorability (e.g., Isola et al., 2011). In a previous study, we extended these results to a more traditional visual long-term memory task, with a separate study and test phase, and longer retention intervals (Goetschalckx et al., 2017). Here, we investigated an incidental type of memory task, with a surprise memory test, and asked how the incidental nature would affect the consistency and ranking of the memorability scores. If memorability is truly an intrinsic property of the image, then one should not expect large differences between incidental and intentional conditions. On the other hand, observers might process images differently when not anticipating a memory test, and therefore different results could be expected. The study list of our incidental memory task was identical to our previous, intentional study. Participants were to watch the images of this list carefully as they appeared on the screen one by one (free viewing). They were told that the study was about eye movements. An actual eye tracker was set up and calibrated to make the cover story credible. Afterwards, a surprise recognition memory test was administered, in which half of the studied images were shown again, mixed with an equal number of randomly selected lures. Incidental memorability scores were computed as the proportion of participants who correctly recognized the target images. Despite the free viewing instructions during the study phase, the incidental memorability scores still showed high levels of consistency across observers (mean split-half Spearman's rho of .44 of for 27 responses per image), although slightly lower than in the intentional study. In addition, there was large overlap between the incidental and intentional memorability ranking: Spearman's rho of .62. These results further support the idea of memorability as an intrinsic image property.

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63.413 **The impact of interruptions on long-term object processing** Lisa M Heisterberg[1](lmheisterberg@gmail.com), Yoolim Hong[2], Andrew B Leber[1,2]; [1]Medical Scientist Training Program & Neuroscience Graduate Program, The Ohio State University, [2]Department of Psychology, The Ohio State University

Interruptions are common in daily life, can negatively affect visual processing, and have important real world consequences. Research has been focused on performance decrements that emerge during task resumption following interruptions, but the persisting long-term consequences of interruptions remain poorly understood. In the present study, we developed a paradigm that was inspired by one introduced by Altmann et al. (2014) to study procedural errors due to interruptions. We incorporated task components allowing for the study of both the immediate and long-term effects of interruptions on object processing. In Phase 1, on each trial participants performed an ordered sequence of 6 judgments on a visual stimulus (e.g., color, size, location, object category). On 50% of trials, participants were interrupted at a random point within the sequence by a letter-copying task. The interrupted stimulus then reappeared, and participants had to resume completion of the sequence from where they left off. In Phase 2, long-term memory was assessed for stimulus features from Phase 1. Phase 1 results indicated interruptions had profound effects on the timely and accurate completion of steps in the sequence. Phase 2 produced two critical findings. First, subsequent memory for spatial and non-spatial kinds of information were differentially affected by interruptions, with interruptions benefiting spatial memory and impairing non-spatial memory. This may be due to strategic spatial marking of objects to help survive interruptions, at the expense of non-spatial properties. Second, we found that long-term memory was most fragile for stimulus properties judged in the sequence immediately before and after the interruptions, revealing how the temporal dynamics of interruptions affect encoding and consolidation of memory. These results begin to characterize how task interruptions affect long-term object processing.

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63.414 **Prior repetition impairs the accessibility, not the fidelity, of new source memory** Do-Joon Yi[1](dojoon.yi@yonsei.ac.kr), Yonsu Kim[1]; [1]Department of Psychology, Yonsei University

In everyday life, we encounter information with various degrees of prior experience. It is not well understood, however, how such familiarity affects the formation of new memories. A previous study demonstrated that repeated exposure of an item decreases its likelihood of associating with new features or locations (Kim et al., 2012). This negative effect of prior experience might be credited either to the reduced probability of retrieval success or to the reduced fidelity of the retrieved representations. The current study compared these two possibilities using a mixture modeling approach (Zhang & Luck, 2008; Sutterer & Awh, 2016). The experiment consisted of three phases. In Phase 1, 30 white silhouettes of objects were presented 10 times. In Phase 2, those 'old' objects and another 30 'new' objects were randomly presented each in a unique color. In Phase 3, white versions of the 60 objects were presented with a color wheel. Participants then recalled and reported each object's color in Phase 2 by clicking on a color wheel. These three phases were repeated six times (total 180 old and 180 new objects). As results (N=28), the RMSE of color memory was greater for the old objects than for the new objects, replicating negative effects of item repetition on source memory (Kim et al., 2012). Next, the aggregated memory errors were fitted to the mixed model using a Bayesian estimation method (Suchow et al., 2013). The resulting posterior distributions of parameter values were compared between two conditions. We found that the probability of guessing (g) was greater for the old objects than for the new objects whereas the fidelity of color memory (SD) was comparable between the old and new objects. Our results suggest that the prior experience of an item may hinder the accessibility, but not the fidelity of new memory representations.

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63.415 **Repetition allows for long-term memories that are as precise as the best working memories** Annalise E Miner[1,2](aeminer@ucsd.edu), Timothy F Brady[2]; [1]Cognitive Science, University of California, San Diego, [2]Psychology, University of California, San Diego

Long-term memory (LTM) can be surprisingly precise (Brady et al., 2013), even when compared to working memory (WM). However, the maximum precision of LTM remains unexplored. In order to quantify the upper bound on the precision of LTM, we looked at how precisely people can remember objects in LTM as we manipulated the amount of exposure to a particular object through repetition. We showed participants arbitrarily colored real-world objects. In the WM condition, they were shown a single object, then after a brief (1s) delay were asked to report the object's color on a color wheel. In the LTM condition, they saw sequences of 40 objects, each repeated either one or two times. Using a mixture model to extract "guess rates" and standard deviation as measures, we found that the WM condition was the most accurate (gr=1.9%; σ=15°), as expected. In LTM, participants had the least accurate memory for non-repeated objects (gr=28.3%; σ=23°), but this accuracy improved significantly for objects repeated twice (gr=18.5%; σ=19°; $p< 0.005$), demonstrating that repetition significantly improves the precision of LTM. In Experiment 2, we increased the number of repetitions of each object. Participants were shown blocks of objects repeated one or eight times, and reported the object's color after a distraction task. The no-repetition condition was similar to previous experiments (gr=50%; σ=21°). The eight-repetition condition's accuracy increased dramatically, to the level of a single item in WM (gr=4.5%; σ=13.6°; improvement: $p< 0.001$). These results show that repetition can be used to increase the accuracy of LTM. Repeating objects only eight times was sufficient to create representations of dozens of objects that were as precise as a single WM item. This demonstrates that the upper bound of the precision of LTM is still not fully understood.

63.416 **Temporal visual statistical learning is enhanced by increasing working memory demands related to sequence members** Kenjin B. Chang[1](kchang@udel.edu), Leeland L. Rogers[1], Timothy J. Vickery[1]; [1]Department of Psychological and Brain Sciences, University of Delaware

Temporal visual statistical learning (VSL) occurs when stimuli are predictive of the identities of subsequently presented stimuli during familiarization. Little is known about how task demands during familiarization affect temporal VSL. To examine this question, we exposed participants (N=60, 20 in each group) to streams of shape images that appeared one at a time while they did a simple detection task (respond to the "jiggle" of a shape), a one-back task (respond to the immediate repetition of a shape), or a two-back task (respond to the two-back repetition of a shape). All groups were exposed to the same number of jiggle, one-back, and two-back events. Unbeknownst to participants, streams were composed of repeating triplets of shapes that always appeared in the same order. After familiarization, participants completed a surprise recognition stage in which they chose between target and foil triplets based on which seemed more familiar, where foils were recomposed triplets that had not been exposed during familiarization. We compared recognition rates across the three task groups, and found that higher working memory demands produced higher rates of recognition. All four groups were significantly better than chance at recognizing target triplets (all $p< .001$ vs chance level of 50%). However, the one-back group performed better than the jiggle-detection group (69.7% vs 56.6% accuracy, p=.03) while the two-back group performed best of all (86.5%, both $p < .005$ vs. the other groups), despite the fact that the two-back task was more challenging than the one-back task during familiarization (slower RTs and lower accuracy, both $p< .005$). In conclusion, holding the contents of a shape stream in working memory enhances learning for temporal contingencies, even when it makes the task more difficult to perform.

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63.417 **Task-relevant category differences strongly influence temporal visual statistical learning** Timothy Vickery[1](tim.vickery@gmail.com), Su Hyoun Park[1], Marian E. Berryhill[2], Valerie M. Beck[1]; [1]Department of Psychological and Brain Sciences, University of Delaware, [2]Department of Psychology, University of Nevada, Reno

Temporal visual statistical learning (VSL) refers to the ability to extract temporal regularities from a succession of visual experiences. Little is known about how stimulus characteristics interact with VSL. In Experiment 1, we investigated how stimulus diversity impacts temporal VSL by presenting streams of face (female/male) and scene (indoor/outdoor) images presented one at a time to subjects. Unbeknownst to subjects, streams were composed of AB pairs of images, where A always predicted the appearance of B, which could be either same (e.g., male-male) or different subcategory (e.g., male-female), or different category (e.g., female-indoor). After familiarization, subjects completed a surprise forced-choice recognition task that pitted target against recombined foil pairs. When asked to detect "jiggle" events during familiarization, recognition was unaffected by categorical diversity. However, when asked to categorize events according to type of face or scene (female/male or indoor/outdoor), subjects were strongly affected by pair composition. Same-subcategory pairs were remembered much better than different-subcategory pairs, implying that categorization advantaged learning for more similar items. However, different-subcategory pairs required switching responses, creating response conflict that could have interfered with learning. In two additional experiments, we examined whether the same-subcategory advantage was due to response interference. Using only face images, in Experiment 2 we asked subjects to respond to gender or respond whether the face was the same or different gender as the preceding face. For same/different responders, we found the same effects of category even for pairs always associated with a response switch. In experiment 3, we flanked faces with congruent or incongruent category labels, reliably inducing response interference for some pairs but not others. We found no effects of response interference during training on

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subsequent memory for pairs. We conclude that temporal VSL is strongly influenced by categories of constituent stimuli, but only when those categories are task-relevant.

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63.418 **Statistical Regularities During Object Encoding Distort Long-term Memory** Paul S Scotti[1](scotti.5@osu.edu), Yoolim Hong[1], Julie D Golomb[1], Andrew B Leber[1]; [1]Department of Psychology, The Ohio State University

Statistical regularities in our visual environment can influence memory formation. For actively maintained representations, the quality of memory representations may be distorted due to distractors, higher order structure, or previous trial exposure (e.g., Brady & Alvarez, 2015; Brady & Tenenbaum, 2013; Huang & Sekuler, 2010). Here, we investigated whether visual long-term memory (VLTM) is similarly subject to distortions driven by statistical regularities. Neural evidence supports the possibility that the same retention and retrieval operations occur for items in both long-term storage and active maintenance (Öztekin, Davachi, & McElree, 2010), suggesting that regularities may distort memory representations past the span of working memory. In the current experiment, participants studied 408 sequentially presented real-world objects and were then tested on their memory for the original color of each object using a continuous color report. During encoding, we biased the sampling of each object's color such that fifty percent of objects were selected from the same randomly determined 90° portion of a color wheel (i.e., rich quadrant). The remaining objects were randomly sampled from the other three quadrants of color space. No matter the original color of the object, participants were significantly biased towards the mean of the rich quadrant during testing. This bias was present regardless of either implicit or explicit awareness of the color manipulation. Probabilistic mixture modeling revealed that these errors toward the rich quadrant could be explained by a biased guessing distribution. In addition, in another experiment where the rich quadrant was rotated 180° for the second half of the study phase, objects continued to be biased towards the original rich quadrant. This was observed even for objects that originally appeared after the rich quadrant was rotated. These findings suggest that the quality of long-term memory representations is systematically and persistently biased by statistical regularities during learning.

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63.419 **How abstract are the representations derived from visual statistical learning?** Su Hyoun Park[1](suhyounp@udel.edu), Leeland L Rogers[1], Timothy J Vickery[1]; [1]Department of Psychological and Brain Sciences, University of Delaware

Learners can extract regularities in an environment, even without explicit cues to structure and in the absence of instruction—this has been termed "statistical learning." Previous studies of statistical learning have mainly focused on the types of statistical relationships that are learned in various contexts, but less work has probed the nature of the resulting representations. In three experiments, we found evidence that visual statistical learning (VSL) can result in flexible and abstract representations. In all experiments, participants were asked to passively view a sequence of novel shapes that always appeared as part of triplet (e.g., ABC) sequence. In a subsequent phase, participants completed a forced-choice recognition task, choosing between exposed triplets (e.g. ABC) or respective foil triplets (e.g., AEI) and embedded pairs (e.g. AB and BC and AC) or foil pairs (e.g., AE). We compared recognition rates of non-adjacent items (i.e., AC) and completely randomized order of the target triplets or pairs (e.g., ACB, BAC, and CAB) to chance and to adjacent items and correctly-ordered shape sequences. The accuracy rate of all target triplets and pairs were significantly higher than chance level (0.5), and we noted that learning occurred for non-adjacent items too. There were no differences between triplet, AB, and BC pairs in their accuracy rate, but the accuracy rate for AC pairs are significantly lower than those of three other conditions. In addition, the accuracy rate of all possible orders of target triplets and pairs were significantly higher than chance, and there were no differences between canonical orderings and their corresponding randomized orderings. Our work demonstrates a robust and replicable learning of remote pairs of items and even showed that VSL appeared to support learning that abstracted over initially presented orderings, which support the proposition of flexible and abstract representations during VSL.

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63.420 **Representation in activated long-term memory is not sufficient to induce an attentional control setting** Lindsay Plater[1](lplater@uoguelph.ca), Naseem Al-Aidroos[1]; [1]Department of Psychology, College of Social and Applied Human Sciences, University of Guelph

Recent work in our lab has shown that participants can adopt an attentional control set (ACS) for 30 visual objects, indicating that the contents of ACSs can be stored in long-term memory (LTM). It has been suggested that ACS representations may be stored with greater than normal baseline activation—a state referred to as activated LTM (ALTM)—however, it has yet to be directly tested whether representing an object in ALTM is sufficient to induce an ACS for that object. In the present study, we induce participants to represent objects in ALTM using a working memory change detection task similar to Oberauer's (2001, JEP:LMC) modified Sternberg task, and test whether objects represented in ALTM form an ACS using a spatial blink task. Participants were presented with two sets of objects (set sizes 1 or 3 for each set) for retention in working memory, and were cued that one set was irrelevant. Following the cue, mixed across trials we either probed participants' memory to assess the state of representation of irrelevant items, or used a spatial blink task to assess whether irrelevant items capture attention. On working memory trials, we found the number of relevant objects affected response times (RTs), but the number of irrelevant objects did not; this suggests that participants successfully transferred irrelevant objects out of working memory. Irrelevant objects produced an intrusion effect (slower rejection of irrelevant probes than novel probes), indicating that they were represented in ALTM. Critically, on spatial blink trials, irrelevant items presented as distractors did not impair performance, indicating that irrelevant objects were not part of participants' ACS. These results support the conclusion that representing objects in ALTM is not sufficient to induce an ACS for those objects. More broadly, the present findings enhance our understanding of how long-term memory and visual attention interact.

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63.421 **Attraction to the recent past in aesthetic judgments: a positive serial dependency for ratings of artwork** Sujin Kim[1](preikestolen89@gmail.com), David Alais[1]; [1]School of Psychology, The University of Sydney

Recent work shows that current visual perception can be systematically biased towards recently viewed stimuli. This is known as positive serial dependency and has been shown for various low-level visual features (e.g., orientation) and facial attractiveness. In the current study, we tested whether serial dependency is present in aesthetic judgments of artworks. A set of 100 paintings was collected through online archives (portraits and paintings containing people were excluded). For each of 17 participants, 40 paintings were randomly selected from the set and each was rated 20 times in a random order, with the constraint that the same painting was never presented consecutively. Paintings were presented for 1 s followed by a slide bar that was used to rate attractiveness. We measured the serial dependency effect for each observer by classifying their response on every trial into one of two categories depending on whether the current painting was preceded by a more attractive or less attractive painting (determined by the average of the 20 ratings for each painting). Results showed that the current painting earned significantly higher aesthetic ratings when participants viewed more attractive painting on the previous trial, compared to when they viewed a less attractive one. Significant positive dependencies were also found for 2-back and 3-back analyses. Our data show that positive serial dependencies in perception are not limited to low-level stimuli: high-level judgements such as aesthetics are also assimilated towards the recent past. This finding shows that the aesthetic experience of artworks is influenced by the order in which they are viewed and has meaningful implications for real-world visual environments such as art exhibitions and museums.

Perceptual Organization: Shapes and objects

Wednesday, May 23, 8:30 am - 12:30 pm

Poster Session, Pavilion

63.422 **Size and Aspect Ratio Judgments in Younger and Older Adults** Jessica N Cali[1](calij@mcmaster.ca), Patrick J Bennett[1], Allison B Sekuler[1,2,3]; [1]Department of Psychology Neuroscience & Behaviour, McMaster University, [2]Rotman Research Institute, Baycrest Health Sciences, [3]Department of Psychology, University of Toronto

Size and aspect ratio are attributes of two-dimensional shapes that are hypothesized to be encoded by mid-level visual areas, and are thought to be important for shape and object perception. Shape and object perception is affected by aging, but it is unclear if these age-related changes are due to changes in sensitivity to size or aspect ratio. To address this issue, we measured sensitivity to changes in aspect ratio and relative size in two groups of older adults (M = 67 and 72 years) and younger adults (M = 21 and 20 years). In the aspect ratio task, observers viewed a centrally positioned moving rectangular and reported whether the figure was longer vertically or horizontally. In the size task, observers viewed a moving reference rectangle for 300 ms followed by a moving test rectangle, and reported whether the second figure was larger or smaller than the reference. Stimulus duration was varied between 15 and 210 ms. Psychometric functions were fit to the data to estimate 70% discrimination thresholds. Observers completed the tasks in three conditions: 1) complete, with the entire outline of the rectangle visible; 2) fragmented, with corners of the rectangle deleted; and 3) occluded, resembling the fragmented condition, except with corners occluded by opaque squares. In conditions 2 and 3, perceptual completion of the rectangle was expected to aid judgment of size or aspect ratio. In both tasks, thresholds were higher in older adults, suggesting that older adults may experience a general deficit in shape perception. Thresholds in both age groups decreased as a function of stimulus duration, and were lower in the size discrimination task than in the aspect ratio task. We are currently exploring how differences in the three stimulus types may be related to how performance changes with stimulus duration

63.423 **Evaluating Shape Representations using Machine Learning Systems** Michael Slugocki[1](slugocm@mcmaster.ca), Allison B. Sekuler[2,3,1], Patrick J. Bennett[1]; [1]Department of Psychology, Neuroscience & Behaviour, McMaster University , [2]Rotman Research Institute, Baycrest Health Sciences, [3]Department of Psychology, University of Toronto

Significant progress has been made toward understanding and modeling how the visual system constructs intermediate shape representations from constituent contour elements (Loffler, 2008; 2015). However, less is known about how various shape-encoding schemes affect performance in higher level tasks, such as object recognition. The current study examined how different shape representations constrain performance in a shape classification task. Specifically, we measured how changing encoding schemes affected the classification performance of several machine learning systems on a set of 10 unique shape classes, each consisting of 10,000 samples. The samples were constructed from a set of Radial Frequency (RF) contours, which allowed us to manipulate the low-level properties shared both within and between shape classes. We found that classification performance for sparse representations based upon the radial position of either positive or negative curvature extrema was generally high across machine learning methods, and was very robust to signal noise. In contrast, encoding schemes based upon angularity between neighbouring curvature extrema generally led to worse performance across all learning systems, and for a subset of these systems, introduction of noise into this representation type greatly affected performance. We currently are exploring how alternative encoding strategies can be used to learn to classify different families of shapes. These results highlight the utility in using machine learning methods to probe how different encoding schemas may contribute to the learning of shape identities.

Acknowledgement: NSERC

63.424 **Is shape coding elementary?** David R Badcock[1](david.badcock@uwa.edu.au), Yi Shin Victoria Wong[1], J. Edwin Dickinson[1]; [1]School of Psychological Science, The University of Western Australia

The visual world is a complex jumble of lines and edges representing objects and their backgrounds. The visual system groups these signals to form the boundaries of contours so that objects can be segmented from each other to recognize and interact with them appropriately. Integration of information around contours has been demonstrated with low radial frequency (RF) patterns but cannot be demonstrated for all patterns. Biederman has suggested that matched concavities can trigger segmentation of a contour. This project uses integration as a tool to examine when matched concavities lead to the segmentation of complex contours into elemental parts. This study uses radial frequency patterns, deformed circular shapes, which drive global contour integration, as elements, extending previous work to look at more complex shapes. Three psychophysical shape discrimination experiments were conducted, investigating contour integration within patterns, between two separate patterns, and in patterns that are overlapped to vary the depth of contour concavities to either form a single object or an interpretation of two overlapping objects. Two interval forced-choice shape discrimination methods were used to intensively investigate rules driving performance in six observers. The results show that information interpreted to be on an unsegmented complex contour did not reflect integration, while information interpreted to be on continuous contours perceptually segmented into elemental RF patterns was integrated within an element but the elements were separately processed and performance was precisely predicted by assuming probability summation between two separately integrated patterns. Overall the research suggests that while contour integration is seen when observers are detecting elementary shapes, more complex patterns, even if produced by combining those elementary shapes, do not always yield results reflecting such contour integration. Segmentation at matched deep concavities does allow the integration process on the constituent elements but without the segmentation integration is not observed.

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63.425 **Curvature Discrimination through Kinetic Occlusion** Benjamin A Miller[1](bmill007@ucr.edu), John Andersen[1]; [1]Psychology, University of California Riverside

Kinetic occlusion provides an important source of information for the perception of edge boundaries and allows the visual system to recover surfaces and objects in the environment. Previous work using kinetic occlusion displays found that spatial information has a greater impact on the perception of 2D shapes than does temporal information (Andersen & Cortese, 1989). In the current study we examined the role of kinetic occlusion in distinguishing the magnitude of curvature for different edge boundaries. The displays consisted of two sequentially presented stimuli (a standard and a comparison stimulus) of an opaque object in the center with a continuous background texture translating horizontally. We were interested in whether the discrimination of curved edges and the influence of temporal and spatial information were impacted by the magnitude of curvature. The magnitude of curvature variable had two conditions: in one the curved edge boundary started at a relatively low curvature and increased based on successful performance, while the other condition started at a higher curvature and decreased from there. Thresholds for curvature sensitivity were derived using a QUEST adaptive staircase procedure in a two (density of background texture) by two (velocity of background texture) by two (magnitude of curvature) design. Results matched the findings from our previous work indicating that both spatial and temporal information significantly impact the ability to detect curved edge boundaries. However spatial information was found to have a greater effect than temporal information in the high curvature magnitude condition, matching previous results on 2D shape perception.

63.426 **The automaticity of Tetris: Disconnected 'parts' activate visual representations of their potential 'wholes'** Chenxiao Guan[1](chenxiao@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

Some properties of objects are intrinsic to the objects themselves, whereas other properties encompass that object's relationship to other objects or events in a scene. For example, when completing a jigsaw puzzle, we might notice not only the singular properties of an individual piece (e.g., its particular shape), but also its relationship to other pieces — including its ability to combine with another piece to form a new object. Here, we explore how the visual system represents the potential for two discrete

objects to create something new. Our experiments were inspired by the puzzle game Tetris, in which players combine various shapes to build larger composite objects. Subjects saw a stream of images presented individually, and simply had to respond whenever they saw a certain target image (such as a complete square), and not at any other time. The stream also included distractor images consisting of object-pairs (shaped like the "tetrominoes" of Tetris) that either could or could not combine to produce the subject's target. Accuracy was very high, but subjects occasionally false-alarmed to the distractor images. Remarkably, subjects were more likely to false-alarm to tetromino-pairs that could create their target than to tetromino-pairs that could not, even though both kinds of images were visually dissimilar to the target. We also observed a priming effect, whereby target responses were faster when the previous trial showed tetrominoes that could create the target vs. tetrominoes that could not. Follow-up experiments revealed that these effects were not simply due to a general response bias favoring matching shapes, nor were the results explained simply by representational momentum due to perceived "gravity" (since the effects generalized to 90-degree rotations of the tetromino-pair images). These results suggest that the mind automatically and rapidly evaluates discrete objects for their potential to combine into something new.

Acknowledgement: JHU Science of Learning Institute

63.427 **Vision science at the bar: The role of closure in a powerful geometric illusion** Jose Rivera-Aparicio[1](jriver36@jhu.edu), Chaz Firestone[1]; [1]Department of Psychological and Brain Sciences, Johns Hopkins University

A notoriously tricky "bar bet" proceeds as follows: One patron wagers another that the distance around the rim of a standard pint glass is about twice the glass's height. Surprisingly, this patron is usually correct, owing to a powerful (but, to our knowledge, unexplained) visual illusion wherein we severely underestimate the circumferences of circles. Here, we characterize this illusion and test an explanation of it: We suggest that the difficulty in properly estimating the perimeters of circles and other shapes stems in part from the visual system's representation of such shapes as closed objects, rather than as open contours which might be easier to 'mentally unravel'. Subjects who saw circles of various sizes and adjusted a line to match the circles' circumferences greatly underestimated circumference — initially by a magnitude of over 35%. (Care was taken to exclude subjects who conflated circumference with diameter.) Estimates for these closed circles were then compared to estimates of the perimeter of a circle that was missing a continuous 18-degree segment of arc. We predicted that removing a portion of the circle's perimeter would, paradoxically, cause the circle's perimeter to appear longer, since this violation of closure would bias the visual system to process the stimulus as an open contour. Results revealed that, indeed, this manipulation reliably reduced the magnitude of this "pint glass illusion" by as much as 30%, such that a circle missing a portion of its circumference was judged to have a greater perimeter than a complete, closed circle of the same diameter. We suggest that the property of closure not only influences whether a stimulus is processed as an object, but also constrains how easily such a stimulus can be manipulated in the mind.

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63.428 **Size-contrast illusion induced by unconscious context** Yusuke Nakashima[1](ynakashima@aoni.waseda.jp), So Kanazawa[2], Masami Yamaguchi[3], Yoichi Sugita[4]; [1]The Research and Development Initiative, Chuo University, [2]Department of Psychology, Japan Women's University, [3]Department of Psychology, Chuo University, [4]Department of Psychology, Waseda University

The perceived size of objects is influenced by the size of surrounding contextual objects. Little is known about whether such contextual illusions occur even without conscious processing of the contextual stimuli. The present study examined whether the Ebbinghaus illusion can be induced by surrounding contexts that are suppressed from conscious perception. We employed continuous flash suppression (CFS) to render the contextual stimuli invisible. The surrounding contexts were presented to one eye and the high-contrast and dynamic masking stimulus was presented to the other eye. The two test stimuli were presented to both eyes after the presentation of the surrounding contexts and the masking stimulus, and participants judged which of test stimuli appeared larger. Three different inter-stimulus intervals (ISIs) between the inducer and test stimuli were used to examine decay time of the illusion. We also tested the conditions that the surrounding inducers were visible and not presented. The size-contrast illusion was observed even when the inducers were rendered invisible, although the effect was weak—approximately one third the strength of that induced by visible contexts. The effects induced by both visible and invisible contexts decayed with equal speed as the ISI between the inducer and test stimuli increased. Previous findings have shown that stimuli suppressed by CFS are still processed in V1, but not in the higher visual areas. Our results suggest that the size-contrast effect in the Ebbinghaus illusion is mediated in V1, and the monocular pathway in V1 is involved in the unconscious effect.

63.429 **Object memories alter the appearance of blurry object borders** Diana C Perez[2](dianaperez@email.arizona.edu), Sarah M Cook[1, 2], Mary A Peterson[1, 2, 3]; [1]Department of Psychology, University of Arizona, [2]School of Mind, Brain and Behavior, University of Arizona, [3]Cognitive Science Program, University of Arizona

Do object memories sharpen the perception of familiar objects' borders? Memories represent the norm of previously seen objects; for familiar objects, these are likely to have sharp, focused borders because they have often been fixated and attended. Since perception arises from the integration of the current stimulus with memories, blurry borders might be perceived as sharper in familiar than novel objects. Observers judged whether the borders of two black silhouettes presented on a gray background were the same or different levels of blur. One object was familiar (lamp); the other was a matched novel object created by spatially rearranging the parts of the familiar object. Across trials one of the objects varied in blur (Test) from low to high through 9 levels; the other was held at a constant medium blur (Standard). Both objects served as Standard and Test equally often; their left/right location varied across trials. If object memories influence the perceived sharpness of blurry borders, then the peak of the "same" distribution should be at a higher level of blur when the Test object is familiar rather than novel. We observed this effect in a previous experiment, p < 10-6. There, the pair of stimuli was preceded by masked word primes; on ~17% of trials the word named the familiar object. No effect of word prime was observed. In Experiment 1, we replicated the effects without a word prime, p < 10-7, supporting the hypothesis that memory representations increase the perceived sharpness of the borders of familiar compared to novel objects. Experiment 2 tests the generalizability of these results by using silhouettes of two other familiar objects, each presented alongside their part-rearranged, novel matches. If we replicate the results of Experiment 1, that will support the hypothesis that object memories can alter the appearance of an object.

Acknowledgement: ONR N00014-14-1-067

63.430 **Do Semantic Expectations Arising From Masked Word Primes Aid Object Detection At The Earliest Level? Now You See It, Now You Don't** Rachel M Skocypec[1,2](rachelskocypec@email.arizona.edu), Mary A Peterson[1,2]; [1]Department of Psychology, University of Arizona, [2]Cognitive Science Program, University of Arizona

Do semantic expectations activated by words aid object detection? In two experiments, participants viewed black and white (B/W) test displays divided into two equal-area regions by a central border. One side of the border depicted a familiar object (upright or inverted); the complementary side depicted a novel object. Objects are typically more likely to be detected on the familiar side. Before each test display, a word appeared denoting either the basic level (BL) of the familiar object or an unrelated different-category (natural/artificial) object. Participants reported where they perceived an object relative to the border. Semantic expectation effects would be demonstrated if objects are detected on the familiar side of the border more often following BL than unrelated words. In Experiment 1, subjects categorized unmasked 500-ms words as natural or artificial; 200 ms afterwards, a 90-ms B/W display appeared and was masked. Object detection on the familiar side of the border was reduced for both orientations following unrelated words, but not enhanced following BL words, p < .03. This pattern indicates that semantic expectations affect object detection by interfering when features of the expected object mismatch those of the presented object. In Experiment 2, 50-ms words were rendered unconscious by pre- and post-masking; 120 ms later, a test display appeared. Semantic effects from masked words are notoriously unreliable, and are tuned up/down by task set. To enhance semantic processing of the masked words we randomly intermixed test words requiring semantic categorization with the B/W displays. Word categorization responses were accurate (97%), although response times were ~300 ms longer than in single-task experiments. However, under these task uncertainty conditions the exposure duration of the B/W test display was too short to observe familiarity effects, p = .90, so word type effects could not be assessed. Longer display exposure durations are currently being tested.

Acknowledgement: ONR 00014-14-1-067

63.431 **The Effects of Temporal and Featural Dynamics of the Fovea on Peripheral Perception** Kaleb T Kinder[1](kkinder5@vols.utk.edu), Caglar Tas[1]; [1]University of Tennessee, Knoxville

Previous studies have found two main interactions between foveal and peripheral stimuli. First, it has been shown that pre-saccadic peripheral information is encoded and integrated with post-saccadic foveal information. Second, foveal information has a modulating role for perception of peripheral stimuli in a feedback fashion (Williams et al., 2008). Specifically, this foveal feedback effect is proposed to occur approximately 100ms following the onset of the peripheral stimulus (Weldon, 2016; Yu & Shim, 2016). However, functional roles of this effect have been inconsistent; the presence of a foveal distractor has been shown to both facilitate and impair peripheral perception in discrimination tasks. To resolve this discrepancy, in three experiments we tested the role of target-distractor similarity with a color report task where participants were asked to report the color of the peripheral target while ignoring the foveal distractor. We used three different types of distractors: the distractor shared all the features with the target (match), varied along the color feature (no-match), or did not share any feature with the target (control). As in previous studies, we also manipulated target-distractor SOAs. Contrary to the previous findings, merely presenting a foveal distractor did not have a significant effect on the perception of the peripheral object. Specifically, color reports were accurate for match and control conditions, regardless of the SOA. Instead, we found that the target-distractor similarity significantly affects color reports; reports of the peripheral target's feature were shifted toward the foveal distractor's feature in the no-match condition. This effect was further modulated by the target-distractor SOA, such that these shifts were only seen for negative SOAs where the foveal distractor was presented before the target object. These results contradict the foveal feedback hypothesis and instead support a feed-forward integration account of peripheral perception.

63.432 **Retinotopically specific adaptation reveals different categories of causal events: Launching vs. entraining** Jonathan F Kominsky[1](jkominsky@g.harvard.edu), Brian Scholl[2]; [1]Harvard University, [2]Yale University

Visual processing recovers not only low-level properties such as color and motion, but also seemingly higher-level properties such as causality. In Michotte's 'launching effect', for example, an 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. In this situation, observers have a visceral visual impression that B's motion was caused by A's impact. And among the evidence that this truly reflects visual processing (as opposed to higher-level judgment) is the discovery that causal launching supports retinotopically specific adaptation (Rolfs et al., 2013, Current Biology): viewing causal launching causes a later ambiguous event (in which A and B may overlap to some degree before A stops and B starts moving) to be perceived as non-causal 'passing' – but only if the two events occur in the same retinal location. Does this reflect the detection of some unitary phenomenon of causality, or might vision extract multiple distinct forms of causal perception (as explored by Komsinky et al., 2017, Psychological Science)? Here we use adaptation to ask whether launching is a fundamentally different category from entraining – which is superficially identical to launching, except that A continues to move along with B once they make contact. In contrast to other sorts of causal events (Kominsky & Scholl, 2016, VSS), retinotopically specific adaptation did not transfer between launching and entraining. In particular, adapting to entraining events had no effect on the subsequent perception of ambiguous events as involving launching or passing. We conclude that there are indeed fundamentally distinct categories of causal perception in vision. Furthermore, this emphasizes the sensitivity of the adaptation effect, which is specific enough to distinguish not only between causal and non-causal events, but between different categories of causal events.

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63.433 **The origin of spatial biases: Memory, perception, or action?** Sami R Yousif[1](sami.yousif@yale.edu), Yi-Chia Chen[2], Brian Scholl[1]; [1]Department of Psychology, Yale University, [2]Department of Psychology, Harvard University

Spatial location is surely one of the most fundamental properties that is encoded in the mind. Yet it is striking how biases emerge even in the simplest spatial tasks we can imagine — e.g. when an observer must merely identify the location in which a stimulus appeared. When a dot appears momentarily in a shape, for example, subsequent localization responses are biased away from the shape's primary horizontal and vertical axes (so that, for example, a dot on one of the midlines is mislocalized as having been slightly off the midline). Such spatial biases are powerful (and are clearly visible to the naked eye in aggregated response plots), but also somewhat mysterious. In particular, their underlying nature remains uncertain. Are these biases of spatial memory? Of spatial perception? Of spatial responses? We addressed such challenges by looking for biases in tasks that minimize the demands of memory and perception. In a first study, observers completed a localization task, but one that minimized memory demands. Observers viewed two outlined shapes (e.g. circles) of different sizes, in different locations. A reference dot then appeared on each trial in one of the shapes. Observers' task was simply to place a response dot in the other shape, so that it was in the same relative location as the still-visible reference dot. Observers' responses were again biased away from the shape's horizontal and vertical axes. In a second study, we abandoned localization altogether. Observers completed an unrelated task, and entered their responses using a circular response wheel. The responses in this case were still biased away from the horizontal and vertical axes of the response space. Collectively these results suggest that spatial biases may be more general than has been previously supposed — reflecting not memory, but perception or action instead.

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63.434 **Decoding and reconstructing summary statistical information from human visual cortex** Sol Z Sun[1,2](sol.sun@mail.utoronto.ca), Susanne Ferber[1,3], Jonathan S Cant[2]; [1]University of Toronto, [2]University of Toronto Scarborough, [3]Rotman Research Institute at Baycrest Hospital

Extraction of summary statistics can aid the visual system in overcoming the capacity limits of visual working memory (VWM). By the same token, representations of individual items held in VWM are biased towards the average of the set. While the processing of single items versus ensembles of items has been studied extensively using behavioral paradigms, less is known about the neural mechanisms mediating these processes. Thus, we investigated the processing of single items versus ensembles using fMRI. Participants completed a challenging VWM task where, on any given trial, eight oriented isosceles triangles were presented for study. Participants were instructed to remember the orientation of both the individual items, and the average orientation of the entire set. After a 3 s delay period, participants used a continuous free-recall paradigm to report either the orientation of a randomly chosen single item, or the average orientation of the set. By applying a forward encoding model to the BOLD signal during the study and delay periods from regions of early visual cortex (i.e., V1 – V4), we were able to successfully reconstruct tuning functions that corresponded to the average orientation of the entire set. Importantly, this average orientation was never directly presented to participants, as the individual items were separated from the average by at least 30 degrees. Furthermore, we found that the amplitudes of the reconstructed tuning functions were correlated with behavioral recall precision for the average orientation. The same tuning function amplitudes were not correlated with recall precision for the individual items, suggesting that the reconstructions represent the ensemble summary statistic itself, as opposed to noisy representations of the individual items. These results reveal that the dominant representation in early visual cortex can be based on information that was never physically presented on the retina, at least when VWM capacity is exceeded.

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63.435 **The dimensionality of beauty** Qihan Wu[1](qw686@nyu.edu), Aenne A Brielmann[1], Mika S Simoncelli[3], Denis G Pelli[2]; [1]New York University, Department of Psychology, [2]New York University, Center for Neural Science, [3]Stuyvesant High School

Beauty is described as one of the goals of humankind, alongside truth and goodness. Values are the basis for decision making. In decision theory, a rational decision maker's preferences will be transitive along the dimension of expected value. Is beauty a value? Are our beauty preferences transitive? If so, then beauty ratings must be one-dimensional. That is what we test here. Participants are presented with two images simultaneously, one to the left of the central fixation and the other to the right. Then they are asked to choose which one is more beautiful, and rate by how much on a scale from 1-9 (very little to very much). Participants are presented 6-14 images, which are randomly selected from a 45-image subset of the OASIS image database. Independent studies provide normative beauty and valence ratings for the OASIS images. We picked our 45 images to fall into three categories (low, medium, and high) according to beauty and valence ratings. In random order, participants are presented with all possible image pairings, and each pair is presented twice. The SD of repeat testing ranges from 1.4 to 2.6. We assessed how well a one-dimensional beauty model fits each participant's difference ratings. We find that the root mean square error (RMSE) of this one-dimensional model (1.3 to 2.0) is not significantly bigger than expected from the test-retest SD. Thus, we find that beauty is one-dimensional, at least for OASIS images.

63.436 **Perceiving Graphs as Ambiguous Figures** Cindy Xiong[1](cxiong@u.northwestern.edu), Lisanne van Weelden[2], Steven L. Franconeri[1]; [1]Northwestern University, [2]Utrecht University, Utrecht, Netherland

The duck-rabbit and Necker cube illusions reveal that the visual system can lock into a single view of a multi-stable percept (Attneave, 1971). Such ambiguity is rare in the natural world, but ubiquitous in the artificial world of information visualizations. Graphs are one example of ambiguous figures because they contain many perceivable patterns despite providing the same visual stimulation. After viewers extract an initial set of visual statistics about the dataset (Szafir et al., 2016), they exercise top-down attentional control (Egeth et al., 2010) to extract relationships and patterns from the data values (Michal et al., 2016; 2017). This diversity of percepts extractable from patterns in graphs might lead to two people seeing different patterns in the same graph as a function of how they configure that top-down control. In this experiment, participants were shown line graphs and bar graphs depicting a student government election and asked to predict which party would win. They were also asked to indicate which graph features were most visually salient. Critically, the graphs were designed to be ambiguous so that viewers' predictions could differ depending on which features and patterns they attend to. For example, participants who selected certain features, such as more global trends, as the most salient tended to predict a certain party to win, while other participants who selected other features, such as local comparisons, tended to predict the other party to win. Even in the same image, viewers could set themselves to different attentional modes (e.g. global or local) to draw different conclusions from an identical dataset, providing a real-world example of an ambiguous figure.

63.437 **A review of objects versus substances in visual thinking with data visualizations** Caitlyn M McColeman[1](cmccolem@sfu.ca), Steven L Franconeri[1]; [1]Department of Psychology, Northwestern University

The visual system appears to make a fundamental distinction between continuous substances and discrete objects. Visual search can operate over a continuous space of features, but there is also evidence that those features can be clumped into 'preattentive object files' (Wolfe & Bennett, 1997). Visual tracking is possible for discrete objects, but is more difficult for flowing substances (Scholl & vanMarle, 2003). Infants similarly struggle with tracking substances (Hespos, Dora, Rips & Christie, 2012). Some argue that visual number is processed as a distinct feature based on discrete objects, in contrast to judgments of continuous properties such as textural density (Burr, Turi & Anobile, 2010, c.f. Durgin, 2008). We will review how this perceptual distinction between object and continuous substances affects visual thinking abilities in a real-world context: understanding statistical distributions. Distributions may be represented continuously (as line graphs that represent density) or discretely (as icons to represent count). In both continuous and discrete distributions, frequency is usually plotted on the Y axis against observations on the X axis. While the continuous representation is more prevalent in statistics courses and even lay-viewer presentations, the visual processing of frequency over observations as a single continuous value may substantially interfere with a viewer's understanding. In contrast, although rarely used, a discrete representation of stacked objects may trigger a form of visual processing more congruent with counts. We review distinctions between the perception of substances and objects (Rips & Hespos, 2015; vanMarle & Scholl 2003; Soja, Carey & Spelke, 1991; Hespos, Dora, Rips & Christie, 2012). From this review, we identify implications of this substance/object distinction on data visualization, as a case study for extending knowledge in vision science to translational domains.

Acknowledgement: Northwestern University

63.438 **Give me a hand: Investigating the role of visual and response modalities on object-based warping using VR technolog** Joshua E Zosky[1](joshua.e.zosky@gmail.com), Elise R Thayer[1], Timothy J Vickery[2], Michael D Dodd[1]; [1]University of Nebraska - Lincoln, [2]University of Delaware

Previous studies have shown that the perceived distance between two points in a display can be "warped" by the presence of bounding objects, making the bounded points appear further away than they actually are. These studies have traditionally been limited to simple 2D displays requiring a single manual response type. We examined how this effect translates to natural experience by using 3-dimensional objects in a virtual reality environment, and by manipulating response mode to determine their effects on illusory strength. Participants wore an Oculus Rift CV1 virtual reality headset and were instructed to match the distance between their set of dots and a secondary set of static dots under multiple viewing conditions (no object, bounding object, partially occluded bounding object, separate bounding objects for each point). The distance between the static dots could be a small or large and the viewer's distance could be either 1 meter away from the stimuli or 6 meters away. Response modality was manipulated using either a mouse wheel or the Oculus Touch controller with motion tracking. The results indicate that while object-based warping does occur in a similar fashion in 3D, there is considerable variability in performance across conditions and response types relative to standard 2D displays. The strength of the effect was reduced with occluders and with Oculus touch response relative to mouse response (less of an illusion with touch). These results both replicate and extend initial demonstrations of the warping illusion and provide insight into the perceptual vs. response-based contributions to the illusion

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Faces: Gaze, attractiveness, social cues

Wednesday, May 23, 8:30 am - 12:30 pm

Poster Session, Pavilion

63.439 **Face gaze and identity are rooted in independent orientation ranges** Valerie Goffaux[1,2,3](valerie.goffaux@uclouvain.be); [1]Psychological Sciences Research Institute (IPSY), UC Louvain, Belgium, [2]Institute of Neuroscience (IONS), UC Louvain, Belgium, [3]Cognitive Neuroscience Department, Maastricht University, The Netherlands

The horizontal structure of the human face activates face-specialized visual mechanisms and conveys the most optimal cues to face identity and emotion. Face images also contain most energy in the horizontal range. Access to horizontal face structure might therefore facilitate performance in any face-related task. Alternatively, orientation tuning might differ across tasks, reflecting a flexible sampling of face information in the orientation domain. Our recent finding that, in a crowd of faces, observers

Wednesday AM

detect the one that stares straight at them best while relying on vertical information supports the latter alternative. Here we measured the fine-grained sensitivity to direct gaze (DG) at the cardinal ranges (horizontal and vertical) of face information in twenty-five adults. They reported the gaze direction of centrally presented face stimuli as right, left, or direct. Gaze direction ranged from -8° to +8° with respect to DG (0°), in steps of 1.6°. The eyes were filtered to contain horizontal (H), vertical (V), or both (HV) orientations and embedded in a full-spectrum head-model. Proportions of DG responses were fitted with a Gaussian, whose peak and bandwidth respectively estimated the accuracy and selectivity of DG perception. In H and V conditions, DG responses peaked at the veridical DG angle; in HV condition it was slightly biased to the right (from observer's perspective). The bandwidth of the DG response function was narrower for HV and V compared to H range, reflecting a finer selectivity to DG in the vertical orientation-range. In an identification task, performance of the same participants was, as expected, tuned to horizontal orientation. The present findings speak against a generic horizontal advantage for face processing. Rather orientations seem to be sampled in parallel and serve distinct perceptual goals. Thus, orientation-encoding is not exclusively driven by image statistics but modulated by high-level perceptual goals.

63.440 **Contribution of Head and Eye Position to Gaze Discrimination in Human Observers** Borna Mahmoudian[1](bmahmou2@uwo.ca), Hitarth Dalal[2], Diego Piza[1], Rob Nicolson[4], Julio Martinez-Trujillo[1,2,3]; [1]Schulich School of Medicine and Dentistry, [2]Department of Physiology and Pharmacology , [3]Brain and Mind Institute, [4]Children's Health Research Institute

Detecting where other individuals are allocating their gaze is crucial for humans and other primates when assessing their intention to initiate gaze contact. Previous literature has shown the different contributions of gaze and head orientation to gaze contact discrimination in the center and periphery of the visual field. However, to the best our knowledge, all previous studies have assessed this using static images. In the current study we evaluated the contribution of the eye and the head to gaze discrimination by using 3D face models to test participants in a 3-forced choice gaze discrimination task ranging up to 18° of visual angle eccentricity. First we accessed discrimination performance with eye & head aligned (congruent), while in the second experiment we dissociated the orientation of eye & head (incongruent). Lastly we added motion cues in forms of saccadic eye movement to the stimuli tested before and repeated the experiments. Our findings show gaze discrimination errors increase as a function of eccentricity and are significantly greater when eye and head position are incongruent (paired-sample t-test p=0.03, 0.01, 0.01 at 9°, 14° and 18° of eccentricity respectively, df=8) This increase in error was shown to be attributed to an increased reliance on head orientation as a cue for gaze discrimination at larger eccentricities. Lastly, addition of motion cues in form of saccadic eye movement facilitated gaze discrimination in the periphery as well as in the center (paired sample t-test: p=0.03 for 0° of eccentricity in congruent condition, p=0.009 for 9° of eccentricity in incongruent condition, df=7 for all). Our study provides the first model of gaze discrimination that incorporates motion cues and assesses its contribute to gaze contact.

63.441 **Integrated effect of gaze cueing and valence of 'gazed' objects on facial trustworthiness** Risako Shirai[1](RisakoShirai@kwansei.ac.jp), Hirokazu Ogawa[1]; [1] Department of the Integrated Psychological Sciences, Kwansei Gakuin University

Bayliss & Tipper (2006) demonstrated that faces that consistently shifted his/her gaze to subsequent target location in a gaze cueing task were chosen as being more trustworthy than faces that always looked away from it, suggesting that the predictability of the gaze cue affected the trustworthiness judgments of the faces. Furthermore, a recent study demonstrated that gaze-cueing effect was affected by the emotional valence of a target cued at by the gaze (Bayliss, Schuch, & Tipper, 2010). We investigated whether the personality judgment of a face would be affected by the valence of a target as well as the gaze cueing effect. On each trial, a face image with a straight gaze appeared, and then the eyes moved to either the left or right, followed by a target appeared next to the face. There were three types of the faces, each defined by the validity of the gaze cue. Predictive-valid faces always looked at the target. Predictive-invalid faces consistently looked away from the target. Neutral faces did not move their eyes during the trial. The participants had to indicate the location of the target by a key press. The targets were scene images that contained emotionally negative (e.g., snakes) or positive object (e.g., cakes). After the gaze-cueing trial, they evaluated perceived trustworthiness of the face. The results showed that the predictive-valid faces were evaluated more trustworthy than the predictive-invalid faces. Importantly, the predictive-valid faces which looked at the positive target were evaluated more trustworthy than those which looked at the negative targets. Although the valence of the targets modulated perceived trustworthiness of the predictive-invalid faces, the valence did not affect the trustworthiness judgments for the neutral faces. We suggest that the integrated effect of gaze information and the valence of a target would modulate personality impression of the face.

63.442 **Looking into the future: An inward bias in aesthetic experience driven only by gaze cues** Yi-Chia Chen[1](yi-chia.chen@yale.edu), Clara Colombatto[2], Brian Scholl[2]; [1]Department of Psychology, Harvard University, [2]Department of Psychology, Yale University

When you aim your camera at a scene you wish to capture, you face a problem that artists have faced for centuries: How can you best frame your composition? There is no easy answer to this question, since people's aesthetic preferences vary dramatically, and are influenced by personal history and countless cultural factors. There are, nevertheless, some regularities that are powerful enough to persist across people, contexts, and time. For example, in framed images such as photographs, we prefer peripheral figures that face inward (vs. outward). Why does this "inward bias" exist? Since agents tend to act in the direction in which they are facing, one intriguing possibility is that the inward bias reflects a preference to view scenes from a perspective that will allow us to witness those predicted future actions. This account has been difficult to test with previous displays, in which facing direction was often confounded with either global shape profiles or the relative locations of salient features (since, e.g., someone's face is generally more visually interesting than the back of their head). But here we demonstrate a robust inward bias in aesthetic judgment driven by a cue that is socially powerful but visually subtle: averted gaze. Subjects adjusted the positions of people in images to maximize the images' aesthetic appeal. People with direct gaze were not placed preferentially in particular regions, but people with averted gaze were reliably placed so that they appeared to be looking inward. A second experiment with color-inverted images ruled out confounds related to lower-level visual properties, suggesting that the effect is driven by perceived gaze per se. These results demonstrate that the inward bias may be an adaptive feature of our minds: it can arise from visually subtle features, when those features signal how future events may unfold.

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63.443 **The role of spatial-frequency channels in the perception of female facial attractiveness.** Sujin Lee[1](llol5149@hanmail.net), Sohee Jang[1], Kyoudong Lee[1], Hoon Choi[1]; [1]Department of Psychology, Hallym univ.

Though facial attractiveness perception attracted many researchers' interest, only a few studies have explored the relationship between facial attractiveness perception and spatial frequency, using a well-controlled experiment. Some studies focused only on the correlation between them, and other studies employed indirect methods in manipulating spatial frequency information, such as changing the presentation position or exposure time of stimulus rather than transforming the stimulus itself through a spatial-frequency filter. Whereas a number of studies have showed consistently that low-frequency information plays an important role in the perception of male facial attractiveness, it is not the case for female facial attractiveness. The current study performed experiments to examine which spatial frequency was more important for female face attractive perception. High-frequency and low-frequency filters were applied to female face photographs respectively and the attractiveness of each photo was evaluated. Based on this evaluation, the stimulus for the experiment was selected. They were assigned into one of beauty (high attractive both in high and low frequency), high-frequency beauty (high attractive only in high frequency), low-frequency beauty (high attractive only in low frequency), normal (low attractive both in high and low frequency) condition. In Experiment 1, participants were asked to rate the attractiveness of hybrid images with overlapping high-frequency and low-frequency images of identical female model. The results showed that perceived attractiveness in the high-frequency beauty condition was higher than in the low-frequency beauty condition (beauty > high-frequency beauty > low-frequency beauty > normal). In Experiment 2, participants rated the attractiveness of the original photograph, which is a stimulus that can be encountered in real life. The results of Experiment 2 were consistent with Experiment 1. These results indicate that high-frequency information has a stronger influence than low-frequency information in the perception of female face attractiveness.

63.444 **Visual Perception of Facial Attractiveness and Typicality Reflects an Ideal Dimension of Face Category Structure** Logan T Trujillo[1](logant@txstate.edu), Erin M Anderson[2], Judith H Langlois[3]; [1]Psychology, Texas State University, [2]Psychology, Northwestern University, [3]Psychology, University of Texas at Austin

Previous evidence suggests a relationship between the visual perception of human facial attractiveness and the perceived typicality (degree of category representativeness) of a face, with typical faces perceived as attractive and atypical faces perceived as unattractive. However, the relationship between facial attractiveness and the psychological representation of typicality remains unclear. We examined this relationship by gathering human judgments of the attractiveness, typicality, and pairwise similarity of 100 young adult Caucasian female faces. We then described the perceived attractiveness and typicality judgments by fitting three computational models of facial attractiveness and typicality as mathematically expressed within a perceptual "face space" derived from the similarity ratings via multidimensional scaling: 1) the Generalized Context Model, in which attractiveness/typicality is a function of the similarity of a face to other face exemplars in a population of faces; 2) the Central Prototype Model, in which attractiveness/typicality is a function of the similarity of a face to the central tendency of a population of faces; and 3) the Ideal Dimension Model, in which attractiveness/typicality is a function of the distance of a face along a category dimension that reflects a combination of ideal face features. The Ideal Dimension Model described attractiveness and typicality better than the Generalized Context Model or the Central Prototype Model as quantified via measures of model goodness of fit and model generalizability. Our findings suggest that facial attractiveness and typicality are best captured by a single ideal dimension of face category structure.

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63.445 **Influence of lighting direction on the perception of symmetry and attractiveness of faces** Alexandra R Hibble[1](alexandra.hibble@psy.ox.ac.uk), Paul J Azzopardi[1]; [1]University of Oxford

People are exquisitely sensitive to deviations in bilateral symmetry. In faces, symmetry acts as a marker for physical health, and has been implicated as a cue for attractiveness judgements and mate selection. Portrait photographers claim that illumination can increase the attractiveness of their models, presumably as, even in simple shapes, shape perception is biased in the direction of the illuminant. We investigate explicitly whether asymmetric illumination affects the perceived symmetry of faces, and whether this could mediate changes in facial attractiveness. 16 participants underwent a psychophysical symmetry judgement task, where faces generated in FaceGen were manipulated under three horizontal lighting conditions (45o left, frontal, 45o right), and 19 directional symmetry conditions, from 25% leftwards asymmetric, to 25% rightwards. Psychometric curves fitted to the data showed that the point of subjective equality was biased significantly in the direction of the illuminant (Repeated Measures ANOVA, $F(2,30) = 17.224$, $p < 0.001$ $\eta2 = .535$). There was a leftwards bias across thresholds which could be consistent with previously reported preferences for top-left illumination or internalised rightwards asymmetry of Caucasian faces. In two further experiments we investigated whether this perceptual shift in the judgement of symmetry generalised to attractiveness judgements, by testing whether peak attractiveness judgements would be awarded to faces shifted along the asymmetry axis in the direction of the illuminant, the 'perceived symmetry', as per the results of experiment 1. There was a small but non-significant effect of lighting direction, which could be attributed to the relatively small effect size of symmetry on attractiveness compared to other facial attributes, the fact that computer generated and natural faces have different results in the asymmetry-attractiveness literature, and is consistent with research showing that directional asymmetries have a smaller effect on attractiveness judgements than fluctuating asymmetries.

63.446 **I get more attractive with a little help from my friends: Dual mechanisms underlie the cheerleader effect** Daniel J Carragher[1](daniel.carragher@flinders.edu.au), Nicole A Thomas[1], Mike E R Nicholls[1]; [1]College of Education, Psychology, and Social Work, Flinders University, Adelaide, Australia

Faces are perceived to be more attractive when seen in a group than alone, a phenomenon known as 'the cheerleader effect'. The visual system automatically creates ensemble representations of groups, and the recalled characteristics of individual items from the group are biased toward the ensemble average. Across three experiments, we investigated whether the cheerleader effect occurs because the ensemble average of a group of faces has average facial characteristics, which are perceived to be highly attractive. Observers gave attractiveness ratings for target faces shown in a group of faces or objects, and alone. A cheerleader effect measure was created by subtracting the attractiveness of each face when seen alone, from the attractiveness rating when in a group. The largest cheerleader effects, a 1.5% increase, were observed when target faces were presented in groups that could be summarised to give the ensemble representation average facial characteristics; groups with two unique distractor faces (Experiments 1-3), and groups that contained different photographs of the target identity (Experiment 2). Interestingly, the cheerleader effect was significantly reduced, but not eliminated, when the ensemble representation could not have average facial characteristics: when the group contained identical images of the target face (Experiment 1), or when the distractors in the group were houses (Experiment 3a). Interestingly, houses were also perceived to be more attractive in a group of houses than alone (Experiment 3b). Our results demonstrate that the cheerleader effect occurs because individuals are recalled as being similar to a highly attractive ensemble average. We also find, however, that a second mechanism contributes to the cheerleader effect, which is not specific to human faces. We suggest that sample size bias contributes to the cheerleader effect, whereby observers are primed by the numerosity of group size to give higher attractiveness ratings to faces presented in a group.

63.447 **Eyelashes and Attraction: Eyelash Length and Fullness are Significantly Correlated with Facial Attractiveness** Erick Aguinaldo[1](ERAguinaldo@csu.fullerton.edu), Maedeh Mousavi[2], Jessie Peissig[1]; [1]Department of Psychology, College of Humanities and Social Sciences, California State University, Fullerton, [2]Department of Psychology and Social Behavior, School of Social Ecology, University of California, Irvine

Studies suggest that hair quality is an indicator of health and youth in females, and thus potentially related to attractiveness (Etcoff, 1999). Prior research has also shown that the use of mascara plays a key role in attractiveness (Peissig, et al., 2015). Therefore, we propose that eyelash fullness and length may be important for attractiveness judgments of females. To test for a relationship between eyelash length/fullness and attractiveness ratings, we had one group of participants assess just the eyes of a set of 48 faces, half shown with eyes open and half with the eyes closed; assignment of specific faces to open or closed was counterbalanced across participants. This group was given a Likert-like scale to rate the eyelash length and fullness, from 1 to 5, with 1 being short, thin eyelashes and 5 being long, thick eyelashes. Another group of individuals were shown the full face of an individual and rated it on attractiveness using a Likert-like scale from 1 to 7, with 1 being very unattractive and 7 being very attractive. This study showed a significant positive correlation between eyelash quality judgments and attractiveness ratings ($r = 0.47$, $t(94) = 5.25$, $p < .001$). We then collected a new set of faces from nine individuals, with photos of these individuals taken once a week over four weeks. We used the same procedure as the first experiment to test for a correlation between eyelash length/fullness and attractiveness, using multiple images of the same nine individuals, rather than single images from 48 individuals. Once again we found a positive correlation between eyelash length/fullness and attractiveness ($r = 0.51$, $t(33) = 3.38$, $p < .01$).

These results suggest that eyelashes are an important feature for judging facial attractiveness in females, and may help us better understand female attractiveness and makeup use.

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63.448 **Rapid categorization of gender from natural face images in the human brain** Diane Rekow[1](rekow.diane@gmail.com), Jean-Yves Baudouin[1], Bruno Rossion[2], Arnaud Leleu[1]; [1]Group « Developmental Ethology and Cognitive Psychology », Centre des Sciences du Goût et de l'Alimentation, AgroSup Dijon, CNRS, INRA, Université Bourgogne Franche-Comté, F-21000 Dijon, France, [2]Psychological Sciences Research Institute and Institute of Neuroscience, Université catholique de Louvain (UCL), 1348 Louvain-la-Neuve, Belgium Service de Neurologie, Centre Hospitalier Universitaire de Nancy, F-54035 Nancy, France

Human faces are readily and automatically categorized for gender across a wide range of variable cues, a critical visual function for social interactions. To identify an implicit measure of rapid face gender categorization, we recorded scalp electroencephalogram (EEG) from 32 participants (16 females). In a first experiment, highly variable face images from one gender alternated at a rapid rate of 6 Hz (i.e., 6 images per second) with images of the other gender inserted every 6th stimuli, objectively isolating a gender categorization response at a 1 Hz rate in the EEG spectrum. In a second experiment, images from only one gender (i.e., male or female face images) were inserted at the 1 Hz categorization rate in a 6 Hz sequence of non-face objects. In the first experiment, a significant categorization response was identified for both face genders over the right occipito-temporal cortex, but the response was larger for female faces presented among males than the reverse. This asymmetrical pattern suggests either greater generalization across female than male exemplars, or a more inclusive female category. Results from the second experiment provide an answer: a larger generic face categorization response is recorded for male faces, indicating higher generalizability across male than female faces, and thus supporting the second interpretation. Importantly, these effects disappear for upside-down faces, ruling out any contribution of low-level physical variability across images. Moreover, no own-gender bias was found. Altogether, these findings reveal that rapid visual gender categorization from natural face images can be objectively isolated and quantified in the human brain in a few minutes of recording. They also suggest that male faces are highly generalizable within a well-defined category that excludes female faces, while female face category boundaries are less demarcated, female exemplars sharing some male characteristics. Keywords: face gender, categorization, EEG, fast periodic visual stimulation, frequency-tagging

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63.449 **Rapid detection of social interactions in the human brain** Leyla Isik[1](lisik@mit.edu), Anna Mynick[1], Kami Koldewyn[2], Nancy Kanwisher[1]; [1]Department of Brain and Cognitive Sciences, McGovern Institute for Brain Research, MIT, [2]School of Psychology, Bangor University

Understanding a social scene requires not only perceiving individuals, but also detecting and understanding social interactions between them. Humans are adept at perceiving social interactions, an ability that develops early in infancy (Hamlin et al., 2007) and is shared with other primates (Sliwa and Freiwald 2017). We recently identified a region of the human posterior superior temporal sulcus (pSTS) that is selectively engaged when people view third-party social interactions (Isik et al., 2017). These findings underscore the importance of perceiving social interactions, but leave unanswered the question of how quickly and automatically it occurs. Is social interaction detection a rapid, feedforward perceptual process, or a slower post-perceptual inference? To answer this question, we used magnetoencephalography (MEG) decoding to ask when the human brain detects third-party social interactions. In particular, subjects in the MEG viewed snapshots of visually matched real-world scenes containing a pair of people who were either engaged in a social interaction or acting independently (Figure 1). To separate decoding from task demands, subjects performed an orthogonal task. We could read out the presence versus absence of a social interaction from subjects' MEG data extremely quickly, as early as 125 ms after stimulus onset (Figure 2A). This decoding latency is similar to previously reported decoding latencies of primarily feedforward visual processes, such as invariant object recognition (Isik et al., 2014). Importantly, this decoding does not seem to be based on low-level image properties: the images are not decodable based on pixel intensity or the output of a V1-like model, and the social interaction decoding we observed occurs considerably later than the decoding of low-level image identity observed in the same subjects (Figure 2B). These results suggest that the detection of social interactions is a rapid feedforward perceptual process, rather than a slow post-perceptual inference.

63.450 **Looking at faces supports the segmentation of both social and nonsocial events.** Francesca Capozzi[1](francesca.capozzi@mail.mcgill.ca), Jelena Ristic[1]; [1]Department of Psychology, McGill University

People often perceive social and nonsocial events simultaneously. What types of environmental information determine the nature of those event boundaries? Here we tested the role of face cues. Participants viewed a video clip depicting a social interaction between two individuals. Actors' faces were either visible or blurred. In separate counterbalanced blocks, observers were asked to manually mark social and nonsocial events in both visibility conditions. During the task, their eye movements were recorded using a high-speed remote eye tracker. Key press data indicated overlapping social and nonsocial event boundaries in both visibility conditions. Eye-tracking data revealed that extracting information from actors' faces supported both social and nonsocial event segmentation. That is, participants looked more frequently at actor's faces, especially when they were visible. When faces were blurred, however, participants looked equally frequently at actors' faces and bodies. Thus, information conveyed by faces appears to be an important factor in parsing the environmental socio-interactive content into both social and nonsocial events.

63.451 **Social Networks: Analyzing Social Information in Deep Convolutional Neural Networks Trained for Face Identification** Connor J Parde[1](connor.parde@utdallas.edu), Ying Hu[1], Carlos Castillo[2], Swami Sankaranarayanan[2], Alice J O'Toole[1]; [1]School of Behavioral and Brain Sciences, The University of Texas at Dallas, [2]Institute for Advanced Computer Studies, University of Maryland

The state-of-the-art for face identification algorithms has improved due to the development of deep convolutional neural networks (DCNNs) trained on large datasets of face images. We asked whether DCNNs trained for face identification also retain information useful for modeling the social and personality inferences people make spontaneously from faces. Participants (n=80) rated 280 frontal faces on a diverse set of 18 social traits from the Big Five Factors of Personality (Gosling, Rentfrow & Swann, 2003). These five factors are openness, conscientiousness, extroversion, agreeableness, and neuroticism. We predicted the human-assigned social trait ratings for each image from the top-level features produced by a DCNN trained for face recognition, using a cross-validation method to train linear classifiers. This DCNN (Sankaranarayanan et al., 2016) was trained on 494,414 images of 10,575 identities and consisted of seven layers (19.8 million parameters). At the top level, the network produces 512 features for each face image. The top-level features from this DCNN predicted human-assigned social trait profiles (i.e., vectors of trait ratings) well (average cosine similarity between vectors = 0.53, $p < 0.001$). To determine which traits were important for trait-profile estimation accuracy, we tested predictions for individual traits by measuring the error between human-assigned trait ratings and the DCNN-predicted traits. All of the traits were predicted reliably (Bonferroni corrected alpha level = .00225). Next we tested whether trait information could be predicted from DCNN features of profile-view images (90 degrees) of each identity. The results indicated a robust representation of traits across changes in viewpoint ($p < .001$). We conclude that social trait information is well represented at the top level of DCNNs trained for face recognition. This suggests that the information needed for face identification is not domain-specific and can be leveraged to solve a range of face-perception tasks.

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63.452 **Analysing the facial expressions of large audiences during artistic performances** Nick E Barraclough[1](nick.barraclough@york.ac.uk), Richard A Oakes[1,2], Lisa Peschel[2]; [1]Department of Psychology, University of York, Heslington, York, YO10 5DD, [2]Department of Theater Film and Television, University of York, Heslington, York, YO10 5DD

Individuals' experiences of artistic performances are multifaceted, and include affective, cognitive and social elements. Emotions individuals are currently experiencing are reflected in changes in their facial expressions. We explored what information about an audience's emotional experience of artistic performances could be derived from an analysis of audience members' ongoing facial expressions. During 16 different theatrical and cabaret performances we filmed the faces of audience members at 50 frames per second. The Questionnaire of Cognitive and Affective Empathy was administered to a number of audience members before performances, whilst questionnaires were administered after performances to measure audience member reports of emotional experience during the performances. Machine learning (Facereader7) was used to derive 7 different emotional expressions from specific changes in muscle activity in each face, every 20 ms, during the entirety of each performance. Happy facial expressions predicted reports of happy experiences, whilst angry expressions predicted reports of sad experiences; no other expressions predicted other reports of emotional experiences. Higher affective empathy scores predicted increased reports of sadness and anger, and reductions in variance in sad expressions. In contrast, higher cognitive empathy scores predicted increasing variance in sad expressions. We tested the correlation between the facial expressions of each individual and the average audience expressions within the particular performance to examine the audience's emotional synchrony. Audience happy expressions were correlated with each other, and to a lesser extent so were their sad and angry expressions; surprise, fear, disgust and contempt expressions were not correlated. Happy expressions were anti-correlated with sad and angry expressions. Overall, these results indicate that facial expressions during artistic performances can provide different information about individual's emotional experience than self-reports. Expressions of sadness are modulated by individual empathy. Finally, audience facial expression synchrony is only observed in the movement of specific facial muscles.

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63.453 **The Strength of Adaptation to Negative versus Positive Emotional Information Depends on Social Anxiety Status** Erinda Morina[1](Erinda.Morina001@umb.edu), Sarah C. Izen[1], Vivian M. Ciaramitaro[1]; [1]Psychology Department, University of Massachusetts Boston

Identifying emotional information is important for social engagement, but may be disrupted in clinical conditions such as social anxiety (Yoon & Zinbarg, 2007). More specifically, individuals high (HSA) compared to low (LSA) in social anxiety, demonstrate a negative bias in perceiving faces (Silvia et al., 2006). This hypersensitivity to negative emotions in HSA might be rooted in their fear of negative evaluation and maintained via altered adaptation to negative versus positive emotional content. We hypothesized that HSA individuals would adapt less to angry versus happy emotional faces due to their hypersensitivity to threatening stimuli, with less of a difference in adaptation to angry versus happy faces in LSA individuals. We used face adaptation to quantify the processing of happy and angry faces in HSA and LSA individuals. Repeated exposure to an emotional face can alter the perception of subsequent faces such that post-exposure to negative faces, an emotionally neutral face is perceived as more positive. To quantify adaptation strength for each participant, we fit data with a cumulative normal to calculate the point of subjective equality (PSE), where a face is equally likely to be judged angry or happy, and measured the shift in PSE post-adaptation relative to baseline. LSA (n=36) and HSA (n=40) individuals were randomly assigned to adapt happy or adapt angry. They were adapted for 3 minutes to a series of 30 possible faces of a given emotion (100%) with an 8-sec top-up adaptation after each face morph judged as happy or angry. Eight unique face identities (4F,4M) were morphed along an emotional continuum from angry to neutral to happy (+/-80%, 40%, 20% 10%, and 0). We found a significant difference in adapting positive versus negative emotions in HSA individuals, with stronger adaptation to happy compared to angry faces, and no significant difference in LSA individuals.

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63.454 **Personality trait inferences from three-dimensional body shapes** Ying Hu[1](yxh144230@utdallas.edu), Connor J Parde[1], Matthew Q Hill[1], Naureen Mahmood[2], Alice J O'Toole[1]; [1]School of Behavioral and Brain Sciences The University of Texas at Dallas Richardson, TX, USA, [2]Max Planck Institute for Intelligent Systems Tübingen, Germany

People readily infer personality traits from physical appearance. These judgments can be consequential in various settings, ranging from job applications to judicial settings. Trait inferences from the face have been studied primarily. Here we investigated whether people infer personalities from body shapes. We synthesized 140 (70 female; 70 male) three-dimensional bodies, using the Skinned Multi-Person Linear Model (Loper et al., 2015). In this model, each body is represented as a set of coefficients in a PCA space derived from laser scans of over 1700 real bodies. Participants rated each body on 30 social traits. These traits consisted of positive and negative items from the Big Five Factors of Personality (e.g., conscientiousness: self-disciplined +, lazy -) (Gosling, Rentfrow, & Swann, 2003). First, we visualized the structure of the multivariate body-trait space separately for male and female bodies. The main axes captured the valence (good/bad) and agency (active/passive) of the traits. Positive and negative traits within each Big Five domain were contrasted along the main diagonals and main axes of the space. Second, we predicted trait ratings from body shape coefficients using multiple linear regression with cross-validation. Global trait profiles were predicted accurately from body coefficients ($p < .0001$), as was a subset of individual traits (16 for males, 15 for females; Bonferroni corrected $\alpha = .002$). Predictions were most accurate for traits related to extraversion (e.g., enthusiastic, dominant, quiet), conscientiousness (e.g., self-disciplined, disorganized, lazy), and to a lesser extent, openness (e.g., curious, intelligent). Third, we visualized bodies that typified individual traits. This visualization indicated that body weight relates to trait valence and gender-specific shaping (e.g., female, pear-shaped/rectangular; male, wide-shoulder/rectangular) relates to trait agency. The present study takes a first step towards understanding the range, diversity, and reliability of personality inferences made from body shapes.

63.455 **How to Get Away with Murder: The Effect of Hoodies and Glasses on Facial Recognition** Alexis T Drain[1](alexis.drain@csu.fullerton.edu), Rebecca Fisk[1], Cindy M Bukach[2], Iris Blandon-Gitlin[1], Jessie J Peissig[1]; [1]Psychology, Humanities, California State University, Fullerton, [2]Psychology, School of Arts and Sciences, University of Richmond

In this study, we examined how disguises and race might interact to hinder a person's ability to recognize faces. In previous studies, we've found that disguises significantly reduce a person's recognition accuracy (Righi, Peissig, Tarr, 2012). We test whether this reduction is further complicated when the face is of a different race. This study has practical relevance as well; one of the authors on this study has been approached to act as an expert witness in court cases using eyewitness testimony in which the perpetrator's appearance was almost entirely obscured by a disguise. In the learning phase, participants were shown faces that were either of the same race or another race (Asian, Hispanic, or White), and with or without a disguise (hoodie and glasses). After the learning phase, the participants had a 20-minute break during which they completed other unrelated tasks. In the subsequent testing phase, participants determined if a face was old or new; all faces had no disguise during testing. We tested 81 participants, 32 Asian, 29 Hispanic, and 20 White. We found that participants were significantly poorer at recognizing faces that had been disguised with a hoodie and glasses ($F(1) = 188.77$, $p < .001$). They responded that it was a new face 66.3% of the time on those trials, compared to only 39.2% for faces they learned with no disguise. In addition, we found no significant interaction between race of the participant and race of the faces ($F(4) = 1.09$, $p = .37$). These data suggest that using a disguise such as a hoodie and glasses will significantly reduce the ability to recognize the face, casting serious doubt on any eyewitness identification of anyone disguised in this way. In addition, race does not appear to further influence these effects.

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